# American Marten Population Monitoring in the Lake Tahoe Basin

Monitoring Plan Development and Protocol

FINAL REPORT

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## Executive Summary

Herein we describe a science-based monitoring program for the American marten in the Lake Tahoe Basin (LTB). This program is an early-warning system, capable of detecting a biologically significant level of change in the marten population, with statistical rigor. To be most meaningful, a monitoring program should include insights into the cause-and-effect relationships between stressors and anticipated population responses. Thus, the program also includes analytical tools to be able to evaluate the cause-and-effect relationships that anthropogenic stressors may have on influencing the status and trend of the marten population. The program is focused largely on the western and southern portions of the LTB, where according to review of historical and contemporary information, supports most of the LTB's marten population. A limited number of strategic locations are included in the northern and eastern portions of the LTB.

Development of the monitoring program began with creating a conceptual model to link the key anthropogenic stressors in the LTB to their hypothesized responses by the marten population. We then selected several of these population responses to serve as indicators to monitor in order to determine the status and trend in the marten population over time. We selected indicators related to the spatial distribution of martens as the primary indicator and composition (gender) of martens as a secondary indicator to monitor. These indicators will be used in an occupancy-estimation analytical framework to evaluate the status and trend of the marten population and to evaluate the effects of stressors. A 10-year period for assessing trend was selected because this coincides with the planning cycles for USFS administrative units (e.g., LTB Management Unit). To measure the indicators a systematic grid of sampling units was established, each sample unit contains an area exceeding the average male and female home range size, across the entire LTB. We conducted a prospective power analysis to determine the optimal number of sample units to include to be able to detect a 20% decline in the primary indicator over a 10-year period, with 80% power and an $\alpha = 0.15$. This analysis determined that 110 sample units would be necessary to achieve the objectives of the monitoring program. 96 sample units were selected from the western and southern regions of the LTB and 14 from the northern and eastern regions. The optimal sampling frequency for the program is every 3 years, for a total of 4 sampling years over the 10-year monitoring period. The field method uses 3 track plate stations per sample unit, with each station surveyed for a total of 12 consecutive days between the 1st of June through the 15th of August.

The spatial and temporal characteristics, as well as the intensity of stressors (e.g., ski areas, roads, urbanization, vegetation management) will be measured in GIS for each sample unit. Stressor measurements for each sample unit will be compared with marten occurrence data to evaluate their influence using occupancy modeling and an information-theoretic approach. The monitoring program was designed to be capable of providing short (3-year) and long (10-year) evaluation of the status and trend in the marten population as well as evaluate stressor effects, thus it will begin to provide insight (distributional snapshot, retrospective stressor analysis) with the first year of its initiation.

The estimated cost of the program over its 10-year duration is $165,880 for field data collection. The program is flexible and can incorporate changes to its design (e.g., reduction in sample units, measurement of new stressors) to accommodate changes in our understanding and budgetary realties.

## I. Background & Document Objective

### Background

The American marten (*Martes americana*) is a carnivore that occupies high-elevation (5,000-10,000 feet) late-successional conifer forests in the Sierra Nevada (Spencer et al. 1983, Zielinski et al. 2005). The marten is designated as a sensitive species by the California Department of Fish and Game. Trapping seasons for martens in the Sierra Nevada of California were closed in 1954 due to concern for their declines throughout the state (Grinnell et al. 1937, Twinning and Hensley 1947). Concern over the conservation status of martens in California has remained high, due to their lack of recovery in their coastal distribution (Zielinski et al. 2001) and their known and hypothesized sensitivities to anthropogenic stressors (e.g., loss of mature forest, forest fragmentation, ski area effects). Currently, the marten is listed as a species of special concern by the California Department of Fish and Game (Bryliski et al. 1997) a sensitive species by Region 5 of the U.S. Forest Service (MacFarlane 2007).

One goal of the Sierra Nevada Forest Amendment is to protect and recover marten populations in the Sierra Nevada (USDA 2001, 2004). Furthermore, the draft Pathway 2007 vision statement (a planning partnership between the Tahoe Regional Planning Agency [TRPA] and LTMBU) for all native wildlife species is that: "Environmental conditions in the Lake Tahoe Basin support healthy and sustainable native terrestrial and aquatic animal populations and vegetation communities" (TRPA 1996, Pathway 2007). Furthermore, revisions to the LTBMU forest plan and TRPA regional plan are underway which are likely to establish the American marten as a species-of-interest, elevating its management status in the context of land management planning. This designation will require managers to have an increased understanding of the status and trend of the marten population in the LTB, an understanding of what threats to the species exist, and how they can prescribe management and mitigation alternatives to favor the marten's persistence. The development and implementation of a *monitoring* program represents the initiation of a conservation strategy to ensure that management actions will result in a self-sustaining population of American martens in the LTB.

### Document Objective

The objective of this document is to develop a science-based monitoring plan to support the management objective for maintaining a self-sustaining population American martens in the LTB. To achieve the objective of this document, we will begin with a conceptual framework of American marten ecology and likely responses to different stressors. Our first step in developing this model is a review and synthesis of relevant historical and contemporary information on the status and trend of martens in the LTB and a discussion of whether a reference condition can be established. We then list key threats (stressors) to martens in the LTB and use these to help identify the appropriate indicators to monitor. The conceptual model is then used to establish a monitoring program for estimating the status and trend of the selected indicator(s), using a design that balances statistical rigor and cost. And finally, we describe all the necessary tools (e.g., data collection and analysis protocols) to be able to conduct the monitoring program.

## III. Development of a Conceptual Monitoring Framework

### Review of Existing Information on the Status and Distribution of Martens in the LTB

#### Historical Distribution of American martens in the Lake Tahoe Basin

Detailed historical records for martens in the LTB are scarce. Grinnell et al. (1937) reported 9 martens taken from traps between 7,000-8,000 feet near Upper Velma Lake (Desolation Wilderness) in El Dorado county. Martens were described as occurring "chiefly in the high Sierra Nevada above the 6,000-foot level, up to [at least] 10,600 feet" and utilizing largely forest habitats of the Boreal life zones of California, but also making seasonal (summer) use of talus slopes and rock slides (Grinnell et al. 1937). This description of the historical distribution of martens relative to an elevational range and general habitats where they occur includes nearly the entire LTB. Without detailed historical distributional information, it is difficult to assume this was the case. However, combined with contemporary information on distribution-habitat relationships (see below) it is reasonable to conclude that nearly the entire LTB was within the historical range of martens, but their abundance varied by the type and character of the forest habitats (e.g., continuously distributed in mesic red fir forests of the west shore versus patchily distributed in more xeric Jeffrey pine-dominated forests of the east shore) present in the LTB.

#### Current Distribution of American martens in the Lake Tahoe Basin

We compiled the results of *surveys* using *detection* devices (track plates and remote cameras) from research and management efforts conducted in the LTB. From 1993-2005 a total of 486 locations were surveyed using ≥ 1 detection device per location (Table 1.). For simplicity, we did not distinguish between the differences in survey efforts (e.g., number of detection devices, *survey duration*, survey season) and only seek to use their results to indicate overall patterns of *distribution* in the LTB. During this 15-year period of survey effort in the LTB, martens were detected at 36% of all *sample units* (Table 1). Overall, surveys covered the entire geographic extent of the LTB but survey effort and marten detections were not equally distributed across the LTB (Figure 1). Survey effort was generally greater on the west and southeast portions of the LTB and relatively sparse elsewhere (Figure 1). Detections in the northern and eastern portions of the LTB were scarce, with martens only being detected at 1 sample unit to the east and 8 to the north despite 30% of the total survey effort occurring in these two regions (Table 2). Martens were most frequently detected on the western (50% of sites) and southern (31% of sites) portions of the LTB.

Table 1. Summary of survey effort for American martens in the Lake Tahoe Basin, 1993-2007.

| Survey | Year | # Sample Units | # Marten Detections |
|---|---|---|---|
| Project Surveys* | 1993-2000 | 238 | 79 (33%) |
| East Shore | 2005 | 48 | 2 (4%) |
| MSIM** | 2002 | 22 | 9 (41%) |
| Marten-OHV | 2003-04 | 43 | 36 (75%) |
| MSIM* | 2002, 2005 | 58 | 31 (53%) |
| Urban Biodiversity | 2003-04 | 77 | 17 (22%) |
| Total | 1993-2007 | 486 | 174 (36%) |

*Project surveys are surveys done prior to a management action (e.g., thinning)
**MSIM = Multiple Species Inventory and Monitoring study, piloted in the LTB. These include Vertebrate Assemblage-OHV study locations as well.

Table 2. Survey effort and detections of martens by sub regions within the LTB. Survey locations and detections represent unique locations. See Figure 1 for sub region boundaries.

| Subunit | Marten detections (% of locations) | Number survey locations (% of total effort) |
|---|---|---|
| North | 8 (9.6%) | 83 (16.3%) |
| East | 1 (1.5%) | 67 (13.1%) |
| South | 36 (31.6%) | 114 (22.4%) |
| West | 121 (50.1%) | 244 (48.0%) |
| TOTAL | 166 (32.7%) | 508 |

The collection of surveys conducted during the last 15 years suggests that martens appear to be well distributed on the west and south sides of Lake Tahoe, but are scarce to the north and especially to the east of the Lake. The reduction in detections to the north and east of Lake Tahoe are not surprising as these areas are more xeric than the west and south, supporting forest habitats with lower suitability, due to their structure (e.g., more open canopies, fewer large dead woody structures) and composition (e.g., pine dominated), for martens. Campbell's (2007) probability of occurrence model further supports this trend in declining suitability to the north and east of the LTB (Figure 2) based on habitat characteristics. However, there are two notable locations where detection results shift noticeably and habitat suitability does not. The Highway 89 corridor west of Tahoe City and highway 207 (Kingsbury grade) corridor east of Tahoe Village mark distinct transitions in the proportions of sample units with and without detections (Figure 2). These highways and their associated urban development likely represent filters for marten movement and will likely influence the persistence of the martens to the north and east of Lake Tahoe. While the northern subpopulation likely is connected with martens to the north of the LTB, the eastern subpopulation is likely reliant entirely on the southern population for new recruits from dispersal.

Due to the lack of detailed historical information on the distribution of martens in the LTB, we cannot compare the historical information to contemporary to evaluate the contemporary status of the marten population in the LTB. We are left only with contemporary distribution and known habitat relationships for the American marten to define a reference condition. This said, the overall distribution of martens in the LTB is likely similar to what is was historically, especially in the west and south regions of the LTB. Distributional changes, specifically reductions in distribution, are expected in and around the dense residential areas riming the lake as well as some reduction due to the likely isolation of the small population remaining on the east shore of Lake Tahoe. Declining number of detections in the northern and eastern regions of the LTB are expected due to the shifts in the composition and structure of forest habitats from fairly mesic on the west and south to more xeric in the north and east. However, it is likely that anthropogenic effects (e.g., urbanization and highways that fragment these subpopulations) may have contributed to further lowering the potential for these areas to support marten subpopulations. At this time there is no information suitable for evaluating whether a positive or negative trend in the marten population has or is occurring. Thus, we will establish the current distribution reported here as the reference condition from which the monitoring program will be built upon.

### Bioregional Significance of the Lake Tahoe Basin Marten Population

The west shore population represents the only known contiguous linkage for marten populations to the north and south of the Lake Tahoe Basin. Systematic surveys to the west of the LTB and at lower elevations in Placer and El Dorado counties only detected martens at 2 (4%) of 49 sample units (Zielinski et al. 2005). While portions of the Desolation and Granite chief wilderness areas may still harbor martens in some areas that were unsampled, these areas are dominated by large open expanses of granite and highly fragmented patches of forest, unlikely to support martens or promote population connectivity via dispersal. Maintenance of a well-distributed population of martens along the west side of the Lake Tahoe Basin will not only benefit both local conservation of the species, but could be critical for maintaining population and genetic connectivity for martens in the north and central Sierra Nevada.

Development of the Conceptual Model

Monitoring of individual species is done to determine if management actions are having the desired effects on these species. In the LTB, the management objective is to maintain a self-sustaining marten population in the region. **Because our review of the historical and contemporary information on the distribution of martens leads to the conclusion that martens are still well distributed in the LTB, the emphasis of the monitoring program is on maintaining the marten population throughout its contemporary distribution (reference condition; Figure 1).** To ascertain compliance with this management goal will require the initiation of a monitoring program capable of detecting biologically meaningful levels of change in the marten population. If the monitoring program demonstrates a lack of significant change in the marten population, it supports compliance with the management goal. If the monitoring program demonstrates a significant negative change in the marten population, it should trigger specific changes in management practices.

The task of identifying a meaningful change requires some understanding of the levels of change caused by natural intrinsic factors (e.g., severe winters) versus human-caused extrinsic factors (e.g., timber harvest). Both can have population effects, but typically species have had the time to evolve and cope with the natural variation in intrinsic factors while they are not necessarily able to incorporate the additive variation from human-caused extrinsic factors. Not all extrinsic factors may be detrimental to marten populations, those that are, or hypothesized to, are hereafter referred to as stressors.

Stressor effects are evaluated in the context of induced changes to one or more indicators (Noon 2003). Not all stressors are known nor are their relative magnitudes of effects understood a priori. In the case of monitoring marten populations in the LTB, there are a number of potential stressors that affect different portions of the LTB to different degrees. Thus, stressor affects may be working independently in one area or synergistically in another, and potentially in both spatial and temporal scales. All monitoring programs need to acknowledge the complexities while attempting to tease out important stressor effects. However, to embark on a monitoring program that does not include the opportunity to learn about potential stressor effects, through challenging multiple hypothesis about stressor effects with indicator data, misses an important opportunity. The consequence of missing this opportunity would be embracing a monitoring program to detect change, but with no way to indicate what is causing the change.

A monitoring program can be designed to seek indicator-stressor relationships by being retrospective or prospective. Retrospective monitoring or effects-oriented monitoring seeks to find stressor effects after they have occurred by detecting changes in the condition of a species' population (NRC 1995). In contrast, prospective or stress-oriented monitoring attempts to detect the known or suspected cause of an undesirable population effect, before the effect has a chance to become serious (Figure 3). Thus, prospective monitoring, unlike retrospective monitoring, assumes prior knowledge of cause-effect relationships between stressors and indicators (Thornton et al 1994). However, cause-effect relationships for wildlife populations are seldom known with certainty and are usually only suspected. In this case, a hybrid approach is necessary that emphasizes simultaneous indicator and stressor measurement, and modeling the relationships between stressor action, change in state of indicator, and subsequent population effects (Noon 2003).

The hybrid approach is the best design for a monitoring program for American martens in the LTB and is the approach used for effectiveness monitoring of the Northwest Forest Plan (USDA et al. 1993). The first step in the design process for this approach is to develop a list of the hypothesized stressors to marten populations in the LTB. In section V (Identification of Stressors & Selection of Indicators) we will review the existing information on stressors for martens and develop a list relevant to the LTB. A conceptual model then identifies the scale-specific linkages between stressors and the hypothesized population effects. Indicators that are indicative and predictive of the anticipated changes in population condition are then selected for measurement (NRC 1995, 2000, Noon 2003).

Adding further complexity to the interpretation of monitoring results is that when a monitoring program is initiated it begins with the effects of past stressors (e.g., logging and ski resort development) and over the course of additional monitoring seasons incorporates the combined effects of these past and additional future stressors (e.g., fuels treatments; Figure 4). Thus the initial monitoring period provides an opportunity to retrospectively evaluate past management effects by testing hypotheses representing their suspected effects on population indicators. The knowledge gained from this retrospective analysis can be used to better develop stressor-indicator relationships that can be validated with future monitoring data (Figure 5). Thus, the value of using the initial monitoring period to learn from past management, through retrospective analysis, should not be underestimated and this learning opportunity not missed. In section VII, Data Collection and Analysis, we will describe such an approach to implement after the first data collection season.

## Identification of Stressors and Selection of Indicators of Population Status and Change

A stressor is a factor that adversely affects individuals, populations, habitat, and/or prey. While stressors can include those from both anthropogenic (extrinsic) and non-anthropogenic (intrinsic) sources, we focus only on extrinsic stressors, those from anthropogenic sources. Extrinsic stressors are the results of human action and therefore can be altered if necessary through changing of management practices. There are a number of stressors in the LTB that may have had historical and/or contemporary negative effects on marten populations. Historical stressors may have caused declines or local extirpations which may or may not have had time to be reversed since these activities ceased. Historical stressors to American martens in the LTB include trapping, predator & rodent poisoning, logging, and development (Lindstrom et al. 2000). Potential contemporary stressors include some aspects of vegetation management, continued urbanization, increased traffic volumes and speeds on roads, and the development of and recreation related activities at ski resorts. The current status and condition of the marten population will be a product of any lingering effects of past stressors (e.g., areas still not recolonized due to the lack of regeneration of suitable numbers of large live and dead woody structures removed by logging) and its current responses to contemporary stressors. There have been recent reviews of the potential effects that anthropogenic and non-anthropogenic stressors may have on martens in the Sierra Nevada and we do not seek to repeat these efforts here (see USDA 2001, Green in prep). We will provide a brief discussion of the 5 stressors we hypothesize to be the most detrimental to the marten population in the LTB.

### Urbanization

Urbanization has a number of known and potential effects on martens. The conversion of forest habitat to urban uses (e.g., roads, houses) is a direct loss of habitat and the fragmentation of remnant habitat in the vicinity. L. Campbell (pers. comm.) found that marten *occupancy* in the LTB was significantly influenced by the distance to urbanization and the patch size of habitat in the vicinity of urbanization. Indirect effects are the high densities of predators and competitors (e.g., black bears and coyotes) supported by food subsidies (e.g., garbage and other sources) that can increase mortality of martens and reduce natural food resources in the vicinity of urbanization. Finally, the high density of pets, specifically dogs, in urban areas can increase aggressive and potentially fatal encounters for martens and facilitate both natural and non-native disease transmission into the marten population and the animals martens come into contact with.

### Ski Area Development & Operation

There are approximately 25 ski resorts in the Sierra Nevada mountains, nearly all of which occur within the range of the American marten. The Lake Tahoe region includes about half of these resorts, constituting the highest density of resorts in the Sierra Nevada and one of the highest in North America. The development of ski resorts involves the loss and fragmentation of forest habitat thru the removal of trees for creating ski runs, creation of roads, and building of infrastructure (e.g., lifts, buildings). The operation of ski resorts includes the continued compaction of snow, presence of high densities of skiers, and nocturnal grooming activities. All these factors can have negative effects on martens both directly (e.g., females may avoid these areas due to too much disturbance) and indirectly (e.g., snow compaction and forest fragmentation facilitating higher predation rates by coyotes and great horned owls, respectively). While martens have been detected on many ski areas, Kucera (2004) found that the martens present on the Mammoth ski area were nearly all males and only occupied the ski area seasonally.

### Roads

Roads can affect martens by: 1) vehicle collision mortality 2) fragmentation of habitat and population connectivity by acting as buffers, filters, or barriers to marten movement and habitat use; and 3) indirectly by facilitating access by humans and predators (e.g., coyotes following snow compacted routes in winter) that results in mortality or avoidance of the area. Robitalle and Aubry (2000) found that although martens can be detected near roads, they tended to concentrate their activity away from roads. Not all road types have the same effects. Paved roads with high-speed and frequent vehicle traffic likely represent the largest threat for collision mortality and likely contribute the most to the fragmentation of habitat and population connectivity. Secondary dirt roads are likely most used by predators and may indirectly contribute to increased mortality of martens.

### Vegetation Management

We use vegetation management here to define any management activity (e.g., timber harvest, hazard tree removal, fuels treatment) that alters marten habitat. Vegetation management can have both positive and negative effects, which can either have short or long-term temporal impacts. A short-term negative effect of vegetation management is the removal of overhead cover and escape cover, resulting is increased predation rates or avoidance of the site. Canopy cover and some types of escape cover (e.g., dense shrub of small diameter tree boles) can regenerate relatively quickly (e.g., 1-2 decades). Vegetation management can also affect prey. Bull and Blunton (1999) found that fuels treatments in lodgepole pine (*Pinus contorta*) and mixed conifer stands in northeastern Oregon reduced key prey species (snowshoe hair [*Lepus americanus*] and red-backed vole [*Clethrionomys gapperi*]) in treated stands. A critical long-term negative effect is the removal of large-diameter live and dead woody structures, which provide resting and denning locations, and take centuries to regenerate.

### Motorized Recreation

Motorized recreation, which includes off-highway vehicles (OHVs; 4x4s, quads, dirt bikes) and on-snow vehicles (OSVs; snowmobiles) have been considered potential stressors due to the noise, speed, and locations where they can travel. However, Zielinski et al. (2007) found no effects of motorized recreation on marten occupancy or activity patterns of martens at the OHV/OSV use levels they observed in two study areas (including the LTB) in the Sierra Nevada. In peak seasons of OHV/OSV use, martens were naturally active in nocturnal and crepuscular periods of the day while OHV/OSV users were largely diurnal, reducing the potential for encounters. Unless OHV/OSV use increases above the levels observed in this study or OHV/OSV users become more nocturnal/crepuscular in their recreational patterns, motorized recreation will likely remain a non- or minor stressor for martens.

## Linking Stressors to Marten Population Effects

The selection of indicators that reflect a species response to the underlying ecological structural and functional changes resulting from extrinsic stressors requires a well-developed conceptual model of the ecological system being managed (Manley et al. 2000). The foundation of this cause and effect conceptual model is found in Figure 3. The ideal case would be to build a conceptual model from a foundation of knowledge, based on rigorous investigation on how a species responds to individual stressors of interest. In practice, this type of information is either lacking entirely or only available from other geographic portions of a species' range. This latter situation is where our understanding currently stands on how American marten populations respond to environmental changes. Using existing information and hypothesized relationships we developed a conceptual model to link the 5 extrinsic stressors to likely responses by the marten population in the LTB. The first step, was to identify the specific ways in which each stressor affects relevant ecosystem functions. The second step was to link these specific stresses to their ecological consequence, how they result in direct or indirect changes to the system. The third step was to link these stressor induced ecological consequences to marten population responses. It should be clear that this conceptual model (Figure 5) represents a working hypothesis on how stressors affect marten populations in the LTB. The resulting marten population responses are listed in relative order of severity (Figure 5). These responses are related, such that as lower severity effects are felt by a larger proportion of the marten population, they will begin to cause more severe effects (e.g., reduction in distribution and decreased population viability). The strengths of the linkages and the magnitude of their effects will depend on their spatial extent (e.g., how much area is affected), intensity (e.g., degree of stressor effect), temporal attributes (e.g., rate of stress), and synergistic effects when other stressors are also present.

Table 7. Hypothesis about stressor effects on American marten occupancy patterns in the Lake Tahoe Basin.

| Stressors | Hypothesized Effects |
|---|---|
| Urbanization, Ski Resorts, Vegetation Management, Major Roads | 1. Reduced Distribution: Negatively effects occupancy, resulting in absence beyond a certain spatial threshold.<br>2. Reduced Female Occupancy: Females are more sensitive to males and avoid areas at lower development thresholds than males.<br>3. Increased rates of individual turnover (due to reduced survivorship) at sites with the highest levels of urbanization.<br>4. Reduced detection probability due to lower use of habitat near sites with stressor effects. |

## Indicator Selection

In the development of monitoring plans, selection of indicator(s) that directly relate to the monitoring objective are required to provide the most useful inferences. As mentioned in the beginning of this document, the management objective is to maintain the marten population within its contemporary range in the LTB. Following the management objective, the monitoring objective is to monitor the status and trend in the marten population throughout its contemporary distribution in the LTB (Figure 1).

On the basis of the conceptual model and consideration of the management objectives for martens in the LTB, we identify the following candidate indicators : (1) distribution, (2) population size, (3) sex-specific occupancy, and (4) population turnover. Survivorship, reproduction, and population viability assessment are more difficult and costly to estimate and do not readily fit into a monitoring framework. For a general review of *Martes* indicators, see Appendix 2.

### Primary Indicators

One of the most detrimental population responses to one or more stressors is reduction in geographic range. This can occur either through mortality or through permanent movement away from an area that is no longer suitable. To estimate current geographic distribution in the LTB, we will use site occupancy as an indicator.

Equally as important as site occupancy by martens is occupancy by females. Females raise young on their own and need to maintain home ranges with suitable resources (e.g., den sites, prey populations) to enable them to reproduce and raise young until they disperse. Several studies suggest that females may be more sensitive to certain stressors (e.g., ski areas: Kucera 2004) than males. Furthermore females are on average 33% smaller than males and may be more susceptible to mortality from stressors that involve increased encounters with potential predators (e.g., reduction in overhead and escape cover). Occupancy by females provides a more specific indicator of population status than overall occupancy because it estimates the proportion of the LTB that is potentially suitable for reproduction.

Occupancy by martens and occupancy by females both provide distributional information but do not provide information on demographics. However, by using ancillary data collected during the occupancy survey, e.g., gender differentiation of tracks and collection of hair for DNA analysis, we will be able to make general inferences about sex ratios and population size (see Secondary Indicators below).

A one-year estimate of occupancy rates by martens and occupancy rates by females will enable us to estimate the proportion of the LTB that is likely occupied by martens in general and females in particular. Comparison of occupancy rates between two or more time periods will allow for estimating a trend in occupancy rate and to estimate whether an overall decline has occurred. Investigation of the specific locations where changes have occurred will allow for identification of where the declines are actually occurring. Furthermore, patterns of occupancy can be specifically compared to the pattern and intensity of both individual and multiple stressors (e.g., ski areas; see Evaluating Stressor Related Effects). The initial sampling period offers both an opportunity to assess current occupancy rates and –to the extent stressors can be quantified--how stressors influence the occupancy rate. Subsequent sampling periods will primarily provide direct comparison of both overall and site-specific occupancy status and secondarily will be able to provide insight into how occupancy changes relative to changes in the magnitude of stressor intensity (e.g., 2-fold increase in traffic volume on a highway) or spatial extent (e.g., expansion of a ski area) where they occur.

#### Secondary Indicators

The secondary indicators are population size and population turnover and are included to provide additional tools to investigate specific hypotheses about the primary indicators and stressor effects. Secondary indicators require individual identification from DNA in hair samples. By collecting hair samples concurrently with tracks, a number of genetic methods are available to address additional questions. Of concern to LTB managers, as well as anyone interested in using a related index to monitor a *Martes* population, is the relationship between the index proposed here and the true population size. Hair samples can be analyzed using existing genetic markers for martens for DNA fingerprinting to address this concern. DNA analysis can determine how many individuals are present and generate a population estimate. Once individuals are identified, the same sample units can be resampled to make comparisons of turnover rates for individuals between sample units with high and low exposure to stressors. Importantly, these secondary indicators (population size and individual turnover rates) can only be used if hair samples are collected and if additional funds are acquired to support their analysis.

### Identification of Biologically Significant Indicator Thresholds

We propose a monitoring program capable of detecting a 20% decline in occupancy rates by martens. Occupancy rates by female martens are unknown, but will be lower than occupancy for both genders and may be insufficient for detecting changes in occupancy rates over time. Given this unknown, the program will be designed around occupancy rates for all martens, but will attempt to detect changes in and investigate stressor relationships to occupancy by females. Because declines can progress slowly (e.g., a small annual decline) or rapidly, we will provide a design and analytical tools capable of detecting both types of declines. A slow decline requires the determination of the trend of a population over a significant period of time and requires more effort to detect than a rapid decline. A constant 2.2% annual rate of decline results in a 20% decline over a 10-year period. Detecting this level of change over a shorter time period (e.g., say over 3 years) requires less effort. A 20% decline represents a level of change that is significant to a population and that we assume excludes natural fluctuations that may occur due to annual variation (e.g., effect of winter severity on survival). This threshold also matches the minimum standards for the National Inventory and Monitoring

Framework (April 3, 2000, http://www.fs.fed.us/emc/rig/iim) and matches the design for monitoring the southern Sierra fisher population (Zielinski and Mori 2003, Truex 2003).

VI. Monitoring Approach Rationale

Section Objective:

Develop an analytical framework (e.g., sampling frame) appropriate for long-term monitoring of the *status* and *trend* of the marten population in the LTB. For a general review of marten monitoring methods, see Appendix 3.

Sampling Design

Our approach begins by saturating the LTB with a grid of hexagonal sample units, each with an area of sufficient size to assume independence between adjacent sampling units. We evaluated hexagonal sample units with areas of 2.5 $km^2$, that have an area of 406 hectares, which exceeds the mean male (388 ha) and female (324 ha; Simon 1980, Spencer 1981) home range sizes. We also evaluated hexagonal sample units with 3.0 $km^2$, that have an area of 585 hectares, which exceeds the maximum home range sizes estimated for male (537 ha) and female (526 ha) martens in the northern Sierra (Simon 1980, Spencer 1981). The distance between the center points of the 2.5 and 3.0 $km^2$ hexes is 2.16 and 2.59 km, respectively, and therefore, the 3.0 km hex size is more likely to ensure independence between adjacent sample units. One hundred and forty-one 3.0 $km^2$ hexes occur in the LTB with the characteristics to support martens (Table 3, Figure 6).

Table 3. Potential Sample Unit hex statistics for the LTB. We used the predicted probability of marten occurrence from Campbell 2007 to identify hexes with a high (>50%) proportion of habitat with high predicted probability (>50%) of occupancy in each hex.

| Hex Diameter (km) | Area OF Each Hex (ha) | # of Hexes in LTBMU | # of Hexes in Habitat |
|---|---|---|---|
| 2.5 | 406 | 260 | ---- |
| 3.0 | 585 | 183 | 141 |

Sampling Method

The primary detection method is track plates (Zielinski and Kucera 1995). Track plates provide an unambiguous and inexpensive method for distinguishing the tracks of martens from other similar species (Zielinski and Truex 1998). To determine the sex of martens present at each sample unit, we propose to use the track measurement methods described by Slauson et al. (2008). To collect hair samples and provide information for the secondary indicators, each track plate will also include a hair snaring modification, such that hair samples suitable for genetic analysis can be collected concurrently with tracks (see Design of Hair Snare Modification, Appendix 2).

Sample Unit Survey Protocol

_Procedure_: Each sample unit will be comprised of 3 track plate *stations*, 0.5 km apart, in a triangle pattern (Figure 7). Sampling will occur from 1 June thru 15 August.

_Rationale:_ To determine a survey duration with a high probability of detecting martens present in the sample unit, we re-analyzed track plate data collected by Zielinski et al. (2007). The data selected for this analysis were collected on the west side of the LTB in 2003, during the same season (summer, June-Aug) and using the same number of stations per sample unit as we are proposing here. The station spacing used by Zielinski et al. (2007) was half the distance (250 m between stations) that we propose here.

We used program PRESENCE (Version 2.0, Hines 2006) to fit models to the pooled sex and sex specific detection history (e.g., 0011, 0101) data and estimate the parameters of interest (e.g., p = probability of detection). We evaluated 5 models for each dataset and determined that the 1-group with survey-specific probabilities of detection (SSP) model performed the best across all datasets (Table 4). We used the parameter estimates from the 1-group, SSP model to calculate the cumulative detection probabilities for each dataset (pooled sex, male, female) (Figure 8). Using these estimates, a 12-day survey duration, with *visits* every 3 days, yielded detection probabilities >95% for both sexes combined, males, and females (Figure 8). Thus a 12-day, 4-visit sample unit survey protocol should be adequate to ensure an adequate level of detection certainty for this monitoring protocol.

Statistical Considerations

Background

It is essential to determine, a priori, the probability of detecting significant declines and to choose an adequate sample size to be able to detect those changes with an acceptably high probability. The null hypothesis, that there has been no change in the population index over a 10-year period must be tested against the alternative that the population has changed (either increased or decreased: two-tailed test) or declined (one-tailed test). Because the monitoring program is focused on maintaining martens throughout their contemporary distribution in the LTB, we are only concerned with detecting a decline (one-tailed test).

Table 4. Model results for pooled sex and sex specific detection history data from track plate stations collected by Zielinski et al. (2007) during the summer of 2003 in the Lake Tahoe Basin. *w* is the Akaike weight, which is considered the weight of evidence in favor of a model being the best approximating model given the model set. K represents the number of parameters in a model.

| Data Set | Model Rank | Model Name | $\Delta AIC_c$ | *w* | K |
|---|---|---|---|---|---|
| Both Sexes | | | | | |
| | 1 | 2 Group, SSP | 0 | 0.55 | 10 |
| | 2 | 1 Group, SSP | 0.61 | 0.41 | 5 |
| | 3 | 3 Group, SSP | 5.68 | 0.03 | 15 |
| | 4 | 2 Group, CP | 10.31 | 0.00 | 4 |
| | 5 | 1 Group, CP | 12.46 | 0.00 | 2 |
| Male | | | | | |
| | 1 | 1 Group, SSP | 0 | 0.90 | 5 |
| | 2 | 2 Group, SSP | 5.00 | 0.07 | 10 |
| | 3 | 1 Group, CP | 7.34 | 0.02 | 2 |
| | 4 | 2 Group, CP | 10.31 | 0.00 | 4 |
| | 5 | 3 Group, SSP | 11.44 | 0.00 | 15 |
| Female | | | | | |
| | 1 | 1 Group, SSP | 0 | 0.86 | 5 |
| | 2 | 1 Group, CP | 4.40 | 0.10 | 2 |
| | 3 | 2 Group, SSP | 6.90 | 0.03 | 10 |
| | 4 | 2 Group, CP | 8.41 | 0.01 | 4 |
| | 5 | 3 Group, SSP | 11.42 | 0.00 | 15 |

SSP = Survey-specific probability of detection, CP = Constant probability of detection.

### Statistical Power Simulations

We calculated statistical power using two programs written by J. Baldwin (PSW Statistician) using SAS (v8, SAS Institute 1999) that samples simulated datasets created using parameter estimates from field data. For field data we used the same data from Zielinski et al. (2007) used in the previous section (see Sample Unit Survey Protocol). We simulated a decline, set at 20%, in the population index over a 10-year period. We selected a one-tailed test because we are only interested in determining whether the index has declined from one sampling period to the next. Selecting a one-sided test has more power than a two tailed test at the same α level, and thus requires a smaller number of sample units (approximately 50% fewer) and a smaller budget.

For the 10-year trend power analysis, we first had to determine the optimal sampling frequency within the 10-year period. To determine this, we conducted prospective power analyses varying the number of years in which surveys are conducted while holding all other values constant (Table 5). The number of surveys has a small effect on power. However, the most optimal design is for 4 surveys conducted at 3-year intervals and this design will be used for the next phase of the power analysis.

Table 5. The effect of the number of surveys and the survey interval on power. α, ψ, and the number of sample units were set at arbitrary levels and held constant.

| α | Power | Initial Occupancy (ψ) | Sample Units | # Surveys (interval) | Years Sampled |
|---|---|---|---|---|---|
| 0.2 | 0.81 | 0.7 | 90 | 2 (5) | 1,10 |
| 0.2 | 0.76 | 0.7 | 90 | 3 (4) | 1,5,9 |
| 0.2 | 0.84 | 0.7 | 90 | 4 (3) | 1,4,7,10 |
| 0.2 | 0.81 | 0.7 | 90 | 5 (2) | 1,3,5,7,9 |

A prospective power analysis is only useful when realistic values are used for the parameters required to conduct it. In an occupancy modeling power analysis, the initial proportion of sample units occupied (ψ) has a strong influence on the sample size that will be required to detect a decline in the index. To determine a likely range of initial proportions of sample units occupied by martens, we extrapolated from the contemporary surveys effort conducted across the LTB.

Using data from Zielinski et al. 2007, we first determined which of the 183 sample units (3.0 $km^2$) had survey effort (126, 67.7%) and of those how many had marten detections (64, 50.7%). This represents a simplistic lower estimate of the proportion of sample units likely to be occupied. However, because suitable habitat for martens is not uniformly distributed across the LTB, it would be unreasonable to assume that martens would occupy all sample units across the LTB. To remove sites with no or very little suitable habitat we used Campbell's (2007) predicted probability of occurrence coverage to identify sample units that have >50% of the area (>292 ha) of habitat with >50% predicted probability of occurrence. Forty-two (22.9%) of the sample units did not meet these criteria and 141 (76.0%) did. Surveys had been conducted at 25 (59.5%) of the 42 sample units not meeting the suitability criteria and 101 (71.6%) of 141 sample units meeting the suitability criteria. Martens were only detected at 4 (16.0%) of the 25 sample units not meeting the suitability criteria, while they were detected at 60 (59.4%) of the 101 sample units surveyed that met the suitability criteria. We used the proportion of sample units meeting the suitability criteria ~60%, as a more realistic estimate of initial occupancy, and also varied this by ±10% (Table 5). We also included an initial ψ of 0.8 to show how the sample size can be reduced if initial occupancy is higher than we have estimated.

Next, we parameterized the simulation with detection probabilities estimated from field data. We set the number of visits to each sample unit at 4 for each simulation and used the individual visit detection probabilities ($p_1 = 0.43$, $p_2 = 0.43$, $p_3 = 0.61$, $p_4 = 0.86$) generated from track plate data collected during the summer in the LTB using the protocol proposed here (see Zielinski et al. 2007). A markov persistence factor was set at 0.5 to account for the dependence in detection outcomes between visits (Slauson et al. 2008b).

The most realistic estimate of occupancy in the initial sampling period is 0.6, however an occupancy rate of 0.7 would not be unexpected if sample units are selected above some minimal suitability value. Using an occupancy rate of 0.6 and an alpha of 0.15 or 0.20, would require 110 and 140 sample units to detect a 20% decline, respectively (Table 6a). Using an occupancy rate of 0.7 and an alpha of 0.15 or 0.20, would require 80 and 100 sample units to detect a 20% decline, respectively (Table 6a). Based on these statistical considerations, we recommend a sample size of 110 (Table 6a) be randomly selected from the 141 sample units with the minimal suitability criteria. If the initial proportion of sample units occupied from the first year of sampling is ≥0.7, then the sample size could be reduced if desired.

Table 6. Prospective power analysis results for (A) detecting a 20% decline in the marten population index for an entire 10-year period (sampled every 3 years) when there are 4 survey periods and (B) the level of change capable of being detected between any two 2 time periods during the 10-year period, under the varying parameter conditions listed.

A. Trend Over 10-years (4 sampling occasions)

| α | Power | Initial Occupancy (ψ) | Sample Units Required |
|---|---|---|---|
| 0.10 | 0.80 | 0.5 | 250 |
| 0.10 | 0.80 | 0.6 | 175 |
| 0.10 | 0.80 | 0.7 | 120 |
| 0.10 | 0.80 | 0.8 | 80 |
| 0.15 | 0.80 | 0.5 | 200 |
| 0.15 | 0.80 | 0.6 | 140 |
| 0.15 | 0.80 | 0.7 | 100 |
| 0.15 | 0.80 | 0.8 | 65 |
| 0.20 | 0.80 | 0.5 | 160 |
| 0.20 | 0.80 | 0.6 | 110 |
| 0.20 | 0.80 | 0.7 | 80 |
| 0.20 | 0.80 | 0.8 | 50 |

B. Detectable Level of Change Per Sampling Interval (3 Years)

| α | Power (95% C.I.) | Initial Occupancy (psi) | Sample Units | Detectable Decline |
|---|---|---|---|---|
| 0.15 | 0.83 | 0.5 | 110 | 20% |
| 0.15 | 0.81 | 0.6 | 110 | 17% |
| 0.15 | 0.81 | 0.7 | 110 | 15% |
| 0.20 | 0.82 | 0.5 | 110 | 18% |
| 0.20 | 0.81 | 0.6 | 110 | 15% |
| 0.20 | 0.82 | 0.7 | 110 | 12% |

While we have developed the monitoring program to detect a trend over a 10-year period, declines may occur more rapidly. To address this potential we conducted a second power analysis to determine what level of change could be detected between any two sampling periods (3 year interval) given there will be 110 sample units included in the monitoring program. With a sample size of 110, a 12% to >20% to be detected between any two time periods during the 10-year sampling period. Thus, the program is capable of detecting both slow and rapid rates of decline.

Evaluating Stressor Related Effects

Stressors will be treated as site specific covariates and used to explain the patterns of marten occupancy. Models consisting of single stressors and combinations of >1 stressor will be compared to a model without stressor affects (null model). It is important to understand that this analysis will only produce marten-stressor associations, and while they can suggest cause and effect relationships, focused research efforts will be necessary to confirm these relationships. However, the detection of marten-stressor associations, if present, is an important step toward developing management strategies to protect the marten population in the LTB.

We previously identified the four primary stressors and linked them to their hypothesized effects on martens (section III, Figure 5). These hypotheses can be translated into competing models to describe patterns of species and sex-specific occupancy.

The measurement of stressors must take into account the temporal and spatial extent of the stressor as well as its intensity. In addition, each stressor must be measured in a manner appropriate to match the resolution of the marten data being collected. To achieve this match we propose that stressors be measured at the scale of the sample unit and with regard to their spatial extent of influence in each sample unit. Thus for each stressor, a GIS coverage will need to be created to identify the spatial locations of each stressor. For each stressor, we identify important elements of temporal extent and intensity to include in their measurement (Table 8). For example, vegetation management has been conducted in several forms (e.g., selective logging, fuels treatments) occurring over several decades and should be measured to maintain the differences of method and time. Additional stressors can be added to this analytical framework if new information warrants their inclusion.

Table 8. Stressor data layers to be used or created and be used as the basis for measuring stressor influence for each sample unit.

| Stressor | Data Source |
|---|---|
| Urbanization | Parks et al. (in review) Urbanization Index for the LTB |
| Ski Resort | Create a coverage with the footprints of all ski resorts in the LTB |
| Vegetation Management | Fuels Treatments- at this stage a single coverage to identify the areas treated, when they were treated, and how they were treated (e.g., treatment prescription) |
| | Past Logging- assemble a coverage identifying the spatial extent, date when it occurred, and the type (e.g., selective, clearcut) of past logging in the LTB. |
| Major Roads | Use existing coverages to create a single coverage including all the major routes of travel for high-speed (e.g., >35mph) vehicles. Assign each route a relative traffic volume category (e.g., high, medium, low volume). |

## Cost Estimates for Field Data Collection

The final element required to evaluate the number of sample units to be included in the monitoring plan is the cost to collect field data. To generate realistic estimates we will first estimate the total number of hours required to complete a single sample unit. Then this estimate can be multiplied by the total number of sample units and then by the cost to government for field technician time.

Based on our experience deploying the same sample units in the LTB we estimate that, on average, 3 sample units can be set up or checked in a single 10 hour work day. Each sample unit will require 3.33 hours per visit. Each sample unit requires 5 visits, the first to set it up, then 4 checks. Sample units are set up most efficiently with 2 field technicians, while all subsequent visits can be done by a single technician, including the final visit when the sample unit is pulled. Thus each sample unit will require 6 technician visits, equaling (6 * 3.33) = 19.98, or ~ 20 total hours to complete. We used the estimate of 20 hours per sample unit in the Table 9 to illustrate the costs for field data collection for several alternative sample sizes.

Table 9. Estimated costs for field data collection for a single sampling period. All estimates are for FY 2007 costs and do not include annual wage increases. A 25% increase was added to each estimate to include training hours, leave, and unforeseen additional costs. The gray highlighted row indicates the costs for the selected design.

| Number of Sample Units | Total Cost for Field Labor (GS-5 2007 Cost to Govt.) | Sampling Strategy 1-Year Complete | 10 –Year Program* |
|---|---|---|---|
| 45 | [(45 * 20) * $14.88]*1.25 = | $16,740 | $66,960 |
| 55 | [(55 * 20) * $14.88]*1.25 = | $20,460 | $81,840 |
| 65 | [(65 * 20) * $14.88]*1.25 = | $24,180 | $85,920 |
| 70 | [(70 * 20) * $14.88]*1.25 = | $26,040 | $104,160 |
| 80 | [(80 * 20) * $14.88]*1.25 = | $29,760 | $119,040 |
| 110 | [(110 * 20) * $14.88]*1.25 = | $40,920 | $163,680 |
| 140 | [(140 * 20) * $14.88]*1.25 = | $52,080 | $208,320 |

*This is for 4 sampling occasions, once every three years, for 10 years.

Equipment, Data Management, and Analysis Costs

The additional costs for the program include the initial equipment required to conduct the work (Appendix 4) and the support staff time required to supervise field crews, enter and proof data, conduct analysis and write up the results. These costs will depend on the amount on new equipment needed. In general the cost per track plate station (coroplast, aluminum plate, hardware cloth screen, etc) is approximately $20/station. To complete 110 sample units during the survey season (June 1 – August 15), 28 sample units will need to be surveyed simultaneously every 2-week period; resulting in a minimum of 84 stations needed to comply with this schedule. Adding a few extra stations to serve as back ups and for additional sample units during easy sample unit assignments, we recommend the program have 110 stations on hand (110 * $20 = $2,200 for purchasing station supplies). We generally estimate that it will take 2 months of time to confirm and measure marten tracks, enter and proof database. Costs for the previously mentioned duties will depend on whether staff time for existing employees will be dedicated for this project or not. We strongly recommend that the individuals likely to conduct the first year(s) of analysis consult with the principal investigators to ensure proper treatment of the data, proper execution of the analysis, and to be able to incorporate any advances in the types of analysis available for the data.

Sample Unit Selection

Now that we have determined the optimal number of sample units to include in the monitoring program, the next step is to randomly select 110 sample units from the 183 available. The first step in this process is to remove any additional sample units that meet the following criteria: (1) are composed of >80% urban areas (2) have no moderate-high areas of predicted probability of occurrence using Campbell's (2007) model (3) are composed of >50% water (4) have <25% of the sample unit area in the LTB. After removing all sample units not meeting these criteria, only 96 remained on the west and south and only 38 remained on the east and north side of the LTB. The emphasis of the monitoring program is on the western and southern portions of the LTB because it supports the majority of the marten population in the LTB. Thus we selected all 96 sample units remaining in this region (Figure 9). We then selected the 14 sample units with the highest predicted probability of occurrence and/or with historical marten detections in the eastern and northern portions of the LTB (Figure 9). The selection process resulted in 110 sample units for inclusion into the monitoring program.

Sampling Schedule

*Procedure*: All sample units will be sampled in a single year, from 1 June thru 15 August.

*Rationale*: Selection of the sampling period for monitoring should target (1) the period of the year exhibiting the lowest degree of movement of individuals (e.g., dispersal) outside home ranges and (2) the portion of the year maximizing sampling efficiency. This will maximize precision and minimize the cost. We reviewed the existing literature on the timing of marten movements (e.g., Mead 1994, Phillips 1994, Bull and Heater 2001) and used our experience conducting year-round fieldwork in the LTB to create the movement and costs relationships by season in Table 10. The summer period offers the best balance between data precision and field logistics compared to the other seasons. Most records of the onset of dispersal in young of the year are during the end of August (e.g., Phillips 1994). Thus the proposed sampling season will be from 1$^{st}$ June through the 15$^{th}$ of August, which precedes the dispersal season avoiding the period when the population index would be inflated by occupancy of some sample units by juveniles that may not survive there. This period may detect males that leave their home ranges in search of females, but the implications of this possibility are relatively minor.

Table 10. General movement patterns of American martens and logistical (e.g., fieldwork and budget costs) relationships by season.

| Season | American Marten Movements Juvenile | Adult Male | Adult Female | Field Logistics & Costs |
|---|---|---|---|---|
| Fall (Sept-Nov.) | High | Low | Low | Low-High |
| Winter (Dec.-Feb.) | Low | Low | Low | High |
| Spring (Mar.-May) | Moderate | Low | Low | High-Moderate |
| Summer (Jun.-Jul.) | Low | Moderate? | Low | Low |

## VII. Data Collection and Analysis Protocol

Section Objective:

The objective of this section is to provide the details necessary to conduct field data collection, analyze field data, and reach conclusions about the status of marten population in the LTB using the monitoring approach detailed in the previous section.

### Field Protocol

#### Establishing Sample Units

Prior to establishing any sample unit, the sample unit stations should either be plotted on a 1:24,000 USGS topographic map or on a GIS generated map. If hand plotted, a 1:24,000 UTM grid will be necessary to locate the approximate locations for each station. UTMs for stations in all selected sample units can be found in Appendix 5. When necessary, stations can also be plotted on 1:10000 digital ortho quarter quads (DOQQs). Plotting and studying stations locations and access options should allow for the selection of the most safe and efficient access routes into sample units. Coordinates should be programmed in to GPS units as waypoints while in the office, prior to installing the sample unit. Field personnel will use a map, compass, and GPS to navigate within 20 m of station locations.

#### Placement of Track Plate Stations

Once field personnel have identified the station location, a suitable site for setting the track plate station must be selected. Ideally, track plate stations should be established on level terrain so field personnel must create a level surface by digging or piling debris. A level surface is critical for stability of the station, encouraging animals to enter the box, and for the collection of high quality tracks. Track plate stations should be set against a log, rock, tree, shrub or other ground feature. Stations should be further stabilized by piling forest debris (e.g., logs, branches, rocks) on the sides and top of the box. However, make sure not to pile heavy objects on top of the box as these may collapse the box.

After track plate boxes have been built and set up, each track plate should be prepared and baited. Attach contact paper sheets to each track plate prior to leaving for the field using the specifications in Appendix 2. Place track plates at the entrance of each station, as flat as possible, prior to application of toner. Apply a thin layer of toner to the entire entrance portion of the plate. Distribute the toner from a bottle uniformly on the plate and then spread evenly using light dabbing vertical strokes with a make-up brush. After toner is applied, remove the wax cover sheet from the contact paper (exposing the sticky surface), place bait on the rear untonered portion of the plate, and gently slide the plate into the box. Make sure the plate sits flush with the bottom of the box by tapping on the front edge. Place small bits of duff (e.g., bark) under the non-flush edges of the plate when necessary to stabilize it.

Application of Lure

Place a commercial trapping lure (GUSTO™, Minnesota Trapline Products, Pennock, MN, http://www.minntrapprod.com/) on an elevated location near each station. Ideally lure will be applied to the bole of the tree nearest to the track plate station, at a height of approximately 2m. GUSTO is best applied when mixed thoroughly with lanolin at a ratio of roughly 3onces GUSTO/1 lb lanolin.

Monumenting Station Locations

Monument each station location to facilitate accurate resampling. We recommend placing a numbered tree tag in the tree at the station location and 4 alternative tree tags in trees at each of the 4 cardinal directions; each alternative tag is placed at breast height on the tree, facing the station tree.

Station Relocation

Field personnel will create flaglines to connect stations to the access points in the most efficient and safest routes of travel. Each station should be identified with two flags labeled with the appropriate information (Sample unit #, Station, Date established) using a Sharpie™ pen. Flag lines should be dense enough so that the next two flags can be seen when traveling any direction along the route. Two flags will be placed at the point of access (e.g., road or trail) for the sample unit and labeled with 'Access to' and the appropriate sample unit number(s). Flagging must be removed when the sample unit is removed. Alternatively, if GPS units are to be used, only flags in each of the 4 cardinal directions, 10 m from the station and 2-flags at the actual station will be sufficient for efficient relocation.

### Revisits to Stations

Revisits to each sample unit occur every 3 days and the sample unit is removed on the 4th visit (after 12 days). During each visit, gently remove the track plate out of the track plate box and examine it for the presence of tracks. Tracks occurring on the soot or contact paper should be collected. Tracks on toner should first be photographed with a digital camera. First place a metric ruler parallel to the central axis of the best track(s) on the toner. Then label a small piece of paper with the sample unit – station – date and place it next to the rule and track. Then take photos that fill the frame with the track, scale, and site/date label together. Archive digital photos of tracks in a database immediately upon return from the field. Tracks on contact paper should be labeled (do not write over carnivore tracks) with a sharpie (Sample unit #, station: 35-1, date: DD-MMM-YY, observer's 3 initials: KMS), removed from the track plate, and placed in an 8 1/2 x 11 inch acetate document protector. Store document protectors and tracks in a tatum or similar device such that tracks are not folded or crushed. Small squares of contact paper can be used to try and 'lift' tracks on toner only. This process is not always successful and usually alters the tracks such that detailed measurement for sex discrimination may not be possible. However, to do so remove the wax paper cover and firmly place the sticky side on top of the track(s) of interest. While keeping the contact paper completely stable (not sliding laterally), firmly rub the area of the track with your thumb with as much pressure as is tolerable. If successful and a quality track is removed, label it appropriately and place in a document protector. All station visit data is recorded on the Daily Track Plate Form (see Appendix 5 for example) while at the station.

### Collection of hair samples

After inspecting the track plate, remove the binder clips on the track plate box and open the top of the box to inspect the hair snare. If marten tracks are present or suspected, all hairs should be collected. Visually inspect the snare by removing it from the box, if hairs are present, put the snare into the storage container with silica gel indicator desiccant (Sorbead Orange, eCompressedair, Tulsa, OK) and label the container the sample information as the contact paper section with tracks (see description above).

### Bait

Add or replenish bait during every visit. Bait present from the last visit should be removed (wrap it up in excess wax paper and store in sealable baggies) and disposed of in a dumpster. Do not discard old bait in the field, especially near a sample unit!

## Data Management and Analysis Protocol

The following section details the steps involved from after field data are collected to data analysis. The process is a sequential and should follow the sequence presented in Figure 10.

### Field Data Forms, Tracks, and Hair Samples

Field data forms should be stored chronologically. Tracks should be stored by sample unit. Hair samples should be grouped by sample unit and kept in a cool, dry, and dark, airtight container.

### Track Identification

All tracks must be reviewed in the office to confirm field identification of all marten and other species tracks using the morphological and measurement details in Taylor and Raphael (1988), Zielinski and Truex (1998), and track examples at: http://www.fs.fed.us/psw/topics/wildlife/mammal/tracks.shtml).

### Proof Daily Track Plate Forms

After confirming the identity of all tracks, review the Daily Track Plate forms to proof the identification of the species listed on the forms. Be sure to check over all other fields for completeness (e.g., all fields should contain data entries) and correctness. Sign and date each form upon completion of proofing to track this process.

### Sex Discrimination of Tracks

All confirmed marten tracks should be subjected to the evaluation and measurement protocol described in Slauson et al. (submitted; Appendix 4). Two observers should independently measure the tracks to ensure proper measurement and agreement of gender identification.

### Complete Station Summary Forms

The first step in collating field data is to complete a Station Summary Form (see example in Appendix 4) for each station in every sample unit. These forms will combine the data for all visits to each individual station. For each station to be summarized, the Daily Track Plate forms with the data for each visit will be required.

### Create a Database

Create a database format that will allow for the entry of data from station forms. The database should be stable, allow for easy data entry, and for querying for data with output formats suitable for use in statistical programs (e.g., SAS). Additionally, enter all marten occurrences in NRIS Wildlife so that they are available to other Forest Service units.

### Proofing the Database

Once all the data has been entered from the Station Summary Forms, the database will need to be proofed to correct any entry errors. First create individual Station printouts for all stations in the database and then compare the printout from the database with the

Station Summary Forms to confirm accuracy. Sign and date all forms once they have been proofed. Update database with all corrections made. Once the database has been completed, create a backup for the original field forms and database and store the backups at a second location.

Data Analysis

Preparation of the Marten Analysis Dataset

Once the database has been completed and proofed, it can be queried to produce the analysis datasets. Creation of the analysis datasets consists of creating a detection history for martens by visit, across all stations within a sample unit. Each visit to a sample unit will receive a '0' if no martens were detected at any of the 3 stations or a '1' if a marten was detected at 1-3 off the stations. Survey visits missed should be marked with a '.' or equivalent missing data value for the statistical software being used. Thus, a sample unit that detected martens on the $1^{st}$ and $3^{rd}$ visits would have a detection history of 1010. Gender-specific detection histories will also need to be created for all sample units. For each visit to a sample unit, a '0' is entered when no females were detected, '1' if 1-3 stations detected a female marten, and '.' is entered if the track was not identifiable to sex.

Occupancy Estimation, Status, & Trend Analysis

The first step in estimating occupancy is to fit a model to the detection history data. This process follows the example provided in the Sample Unit Survey Protocol section, using the same set of competing models and adding any new models hypothesized to better fit the data. These models will be fit separately to each analysis dataset (e.g., all martens, female only) and for each year of sampling (e.g., 2008, 2011).
The candidate set of models incorporate both standard models included in program PRESENCE (version 2.0, Hines 2006) and custom models representing hypotheses on how additional covariates may influence detection probability. Standard models included covariates that assume *p* is constant across visits (constant *p*), that estimate *p* individually for each visit (visit-specific *p*), and assume that heterogeneity exists in the data such that the data are better modeled if partitioned into two groups (2-groups). Custom models included variables found to be important in the analysis of fisher detection data at track plate and remote camera stations in California (Slauson et al. 2008). Use the SAS analysis procedure listed in Appendix 5 to conduct this analysis.

The relative performance of all models to describe the detection history data are evaluated by comparing their $AIC_c$ values and $AIC_c$ weights ($w$) (Burnham and Anderson 2002). The top model(s) are used to estimate the probability of detection ($p$) and occupancy ($\psi$). Estimates of occupancy ($\psi$) and their associated coefficients of variation (e.g., SE's) will be used for the status and trend analysis described next.

## Status & Trend Analysis

The analysis of monitoring data taken from the same locations over >1 time periods is done using the 'multi-season' trend analysis in program PRESENCE. However, when only two time periods are being analyzed, the procedure simplifies to a paired t-test. For the analysis of the full 10-year trend dataset, the analysis assumes a linear change over time. Further explanation of the statistical procedures can be found in the help menu of program PRESENCE and in MacKenzie et al. 2005.

### Analysis of Stressor Effects

Stressor effects will be evaluated by including each stressor as a 'site' covariate in program PRESENCE. Add the sample unit specific stressor attributes to the marten analysis data set. Run the analysis with the competing model set for sample units with stressor covariates. Relative performance of the models will be assessed using the AIC diagnostics described above.

## Use of Hair Snare Data for Specific Hypothesis Testing

The collection of hair samples allows for the testing of several additional hypotheses that relate to assumptions of the sampling design, testing for stressor-related effects, and investigating the role of density-detection probability relationships. The selection of sample units for these additional efforts will depend on the results of the sample units detecting martens. In general, sample units should be selected that have the best chance to evaluate the hypotheses listed in table 10. These hypotheses are not exclusive and samples from the same sample unit can be used to address more than one of these hypotheses or additional hypotheses not listed. The sample units selected and types of analyses planned should be done with consultation with the principal investigators or other qualified analysts. At the current time, genetic analysis to determine the individual identity of marten from hair samples costs ~$100/sample (M. Schwartz, USFS Carnivore Genetics Laboratory, pers. comm.). Thus, analysis of hair samples should not be done without careful consideration to maximize the use of analysis funds.

## Quality Assurance and Quality Control

### Ensuring Accurate Field Data Collection

Supervisors of field crews should make unannounced visits to sample units with field personnel to evaluate the accuracy of execution of the sampling and data collection protocol. Field supervisors should conduct routine screening of all data forms to ensure completeness and accuracy. Field supervisors are responsible for correcting errors in execution of a field related protocols.

Table 10. Hypotheses to address using individual marten identification data generated from DNA fingerprinting using hair samples from hair snares.

| Hypothesis | How to Test |
|---|---|
| 1. Sample units are independent, adjacent sample units do not detect the same individuals. | Select clusters of adjacent sample units with marten detections. Analyze all hair samples and determine whether any individual are detected at more than 1 sample unit. |
| 2. There is no difference between the number individuals detected in sample units with high versus low stressor exposure. | Select sample units with high and of low stressor exposure. Analyze all hair samples and determine whether the number of individuals present differ. |
| 3. There is no effect of the number of individual martens detected in a sample unit and detection probability. | Determine the number of present across the gradient of detection histories. |

### Evaluation of Data Accuracy

We have previously provided mechanisms for supervisor review of field data, verification of tracks, and proofing of data of field forms, and in the final database.

### Evaluation of Analysis Accuracy

Both interim and final analysis should either be completed in collaboration with the principal monitoring program authors or with others experienced in the analysis and interpretation of the carnivore monitoring data. One or more independent reviews from researchers well qualified to evaluate this type of analysis, the results, and their interpretations is also suggested.

## Equipment and Training

### Field Data Collection

A detailed list of the required equipment is listed in Appendix 4. Individuals involved in field data collection should be well trained in navigation with both GPS and map-compass-altimeter together top have the ability to accurately locate stations. Field personnel should receive training on track identification sufficient to be able to reliably distinguish marten tracks from all others anticipated to occur in the area. Field personnel should be trained in data collection procedures involved. All field personnel should be trained in first aid and in communication protocols (e.g. use of radios). Prior experience in any or all of the above is preferential.

Track Identification and Measurement

Training for track identification should be conducted for all individuals involved in field data collection. These individuals will be responsible for taking care to properly identify, collect, and transfer original field data from track plate stations to the office. They must be able to identify marten tracks or potential marten tracks from all other species and have the ability to transfer tracks from soot to contact paper in the event of soot-only tracks. Measurement and positive identification of tracks should be done indoors and under well lighted conditions. Measurements should be done by as few persons as possible to reduce individual variation and should be done with digital calipers.

Training for track identification should involve reading of the following resources: Taylor and Raphael 1988), Zielinski and Truex (1995), and Slauson et al. (submitted) as well as studying on-line examples of tracks collected from known individuals at: http://www.fs.fed.us/psw/topics/wildlife/mammal/tracks.shtml.

Track measurement for distinguishing sex should be conducted by as few individuals as necessary to reduce observer variation. Ideally, only two individuals should measure tracks independently. Results of measurements should be compared for consistency in sex identification.

VIII. Flexibility in altering the monitoring program

The monitoring program has the capacity to be flexible to some changes. The most significant consideration of alteration of the program should take place after the first year of its implementation. After the first year, actual estimates of initial occupancy will be in hand to determine the most optimal number of sample units to include. If the budget is not available to complete the entire grid of sample units, a subset with a higher initial occupancy level can be strategically selected to monitor, but this should be done cautiously with full consideration of the affect on the program's ability to detect the 10-year trend in change. Significant changes to the program should be done in consultation with the authors or others well experienced with the monitoring and analytical methods used in the program. Additional stressors can be added to the analysis if warranted.

IX. Applicability of this Protocol to other mesocarnivores in the LTB.

The LTB marten monitoring program is designed to be compatible with the national monitoring framework for the Multiple Species Inventory and Monitoring (MSIM; Manley et al. 2006) protocol. It represents a species specific extension. The detection device selected in this protocol, the track plate, are capable of detecting mesocarnivores as large as the fisher and gray fox (*Urocyon cinereoargenteus*; Zielinski et al. 2005). The

only large carnivore species reliably detected by track plates is the American black bear (*Ursus americana*; Zielinski et al. 2005). However, bears do not always leave verifiable tracks, despite visiting and disturbing stations. Two large-bodied mesocarnivores found in the LTB, the coyote (*Canis latrans*) and bobcat (*Felis rufus*), are not reliably detected using track plates (Campbell 2004). Other detection devices (e.g., cameras and open track plates)
can result in somewhat higher frequencies of detection, but still would not yield a high probability of detection of these species with similar survey durations as the 12-day protocol proposed here (Campbell 2004). Coyotes can show both avoidance of detection devices (Gompper et al. 2006) and attraction to them, both of which has been observed in the LTB (Slauson pers. obs, Campbell pers. comm., respectively), confounding the interpretation of detection results. There are no current field methods that could be added to the proposed protocol to include a probability of detection of bobcats and coyotes. In Table 11 we present the species of mesocarnivores potentially present in the LTB and their likelihood, based on synthesis of relevant literature and our judgment, of being detected adequately by the proposed track plate protocol.

Table 11. Species of mesocarnivores known to occur in or near the LTB and their relative detectability using the proposed 3-station track plate protocol.

| Species | Relative Distribution in LTB | Detectability with Proposed Protocol |
|---|---|---|
| American black bear | Widespread | High |
| Mountain lion | Unknown | Low |
| Bobcat | Rare | Low |
| Coyote | Widespread | Low |
| Gray fox | Rare | High |
| Marten | Widespread | High |
| Long-tailed Weasel* | Unknown | Moderate? |
| Short-tailed Weasel* | Unknown | Moderate? |
| Spotted Skunk | Rare | High |
| Striped Skunk | Unknown/Urban Assoc. | High |
| Raccoon | Urban Associate | Moderate? |
| Ringtail | Unknown/Rare | High |

*Weasels are not distinguishable based on track morphology.

Acknowledgements

We would like to thank Jan Werren for GIS support and Christina Voitja for reviewing this document.

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Figure 1.  Distribution and results surveys using detection devices for American martens from 1993-2005 in the Lake Tahoe Basin.

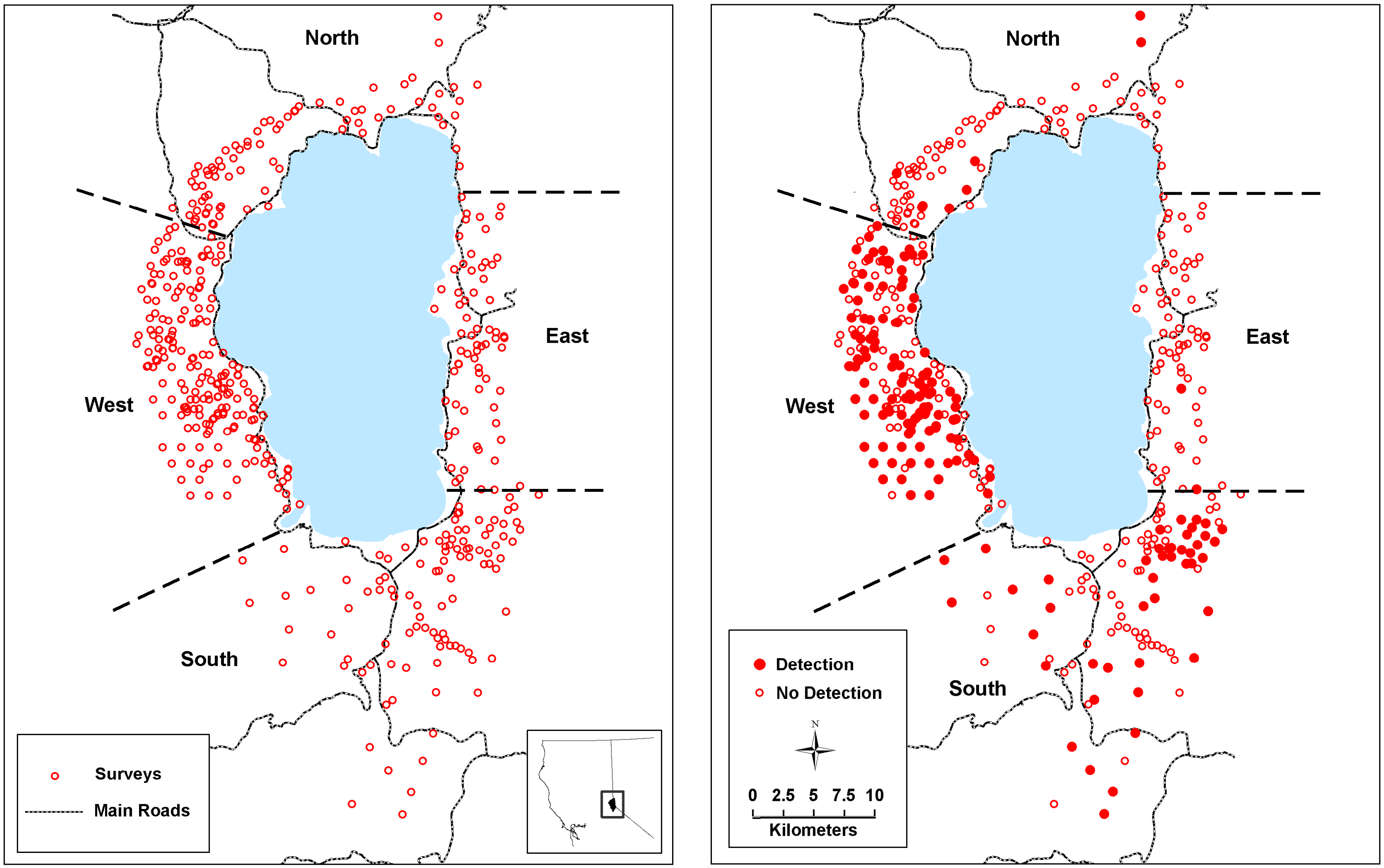
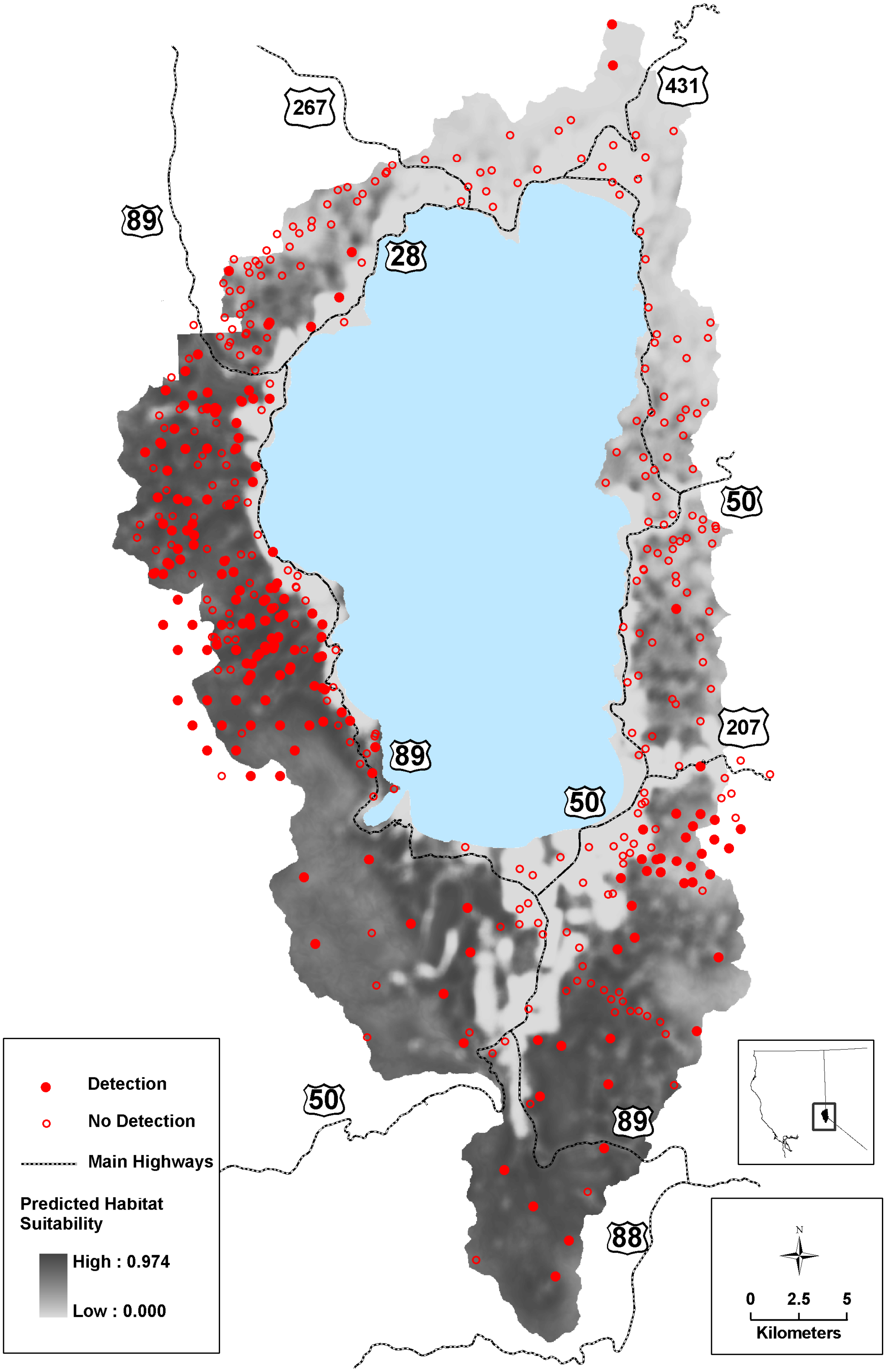


Figure 2. Survey results & Campbell's (2007) predicted probability of marten



occurrence.

Figure 3. Conceptual diagram of a prospective environmental monitoring program. Indicators are selected in the context of known or hypothesized stressors to martens (adopted from Noon 2003).

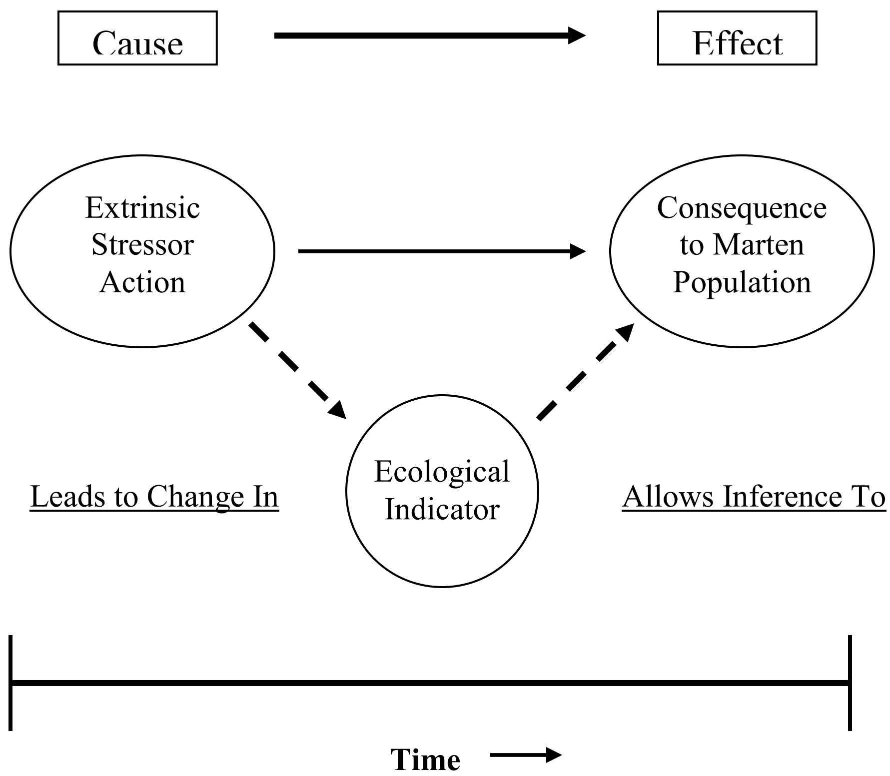


Figure 4. Conceptual model of the relationships between the point of initiation of a monitoring program and retrospective and prospective detection of change. Dashed lines indicate how knowledge gained from retrospective analysis will be incorporated into prospective detection of change.

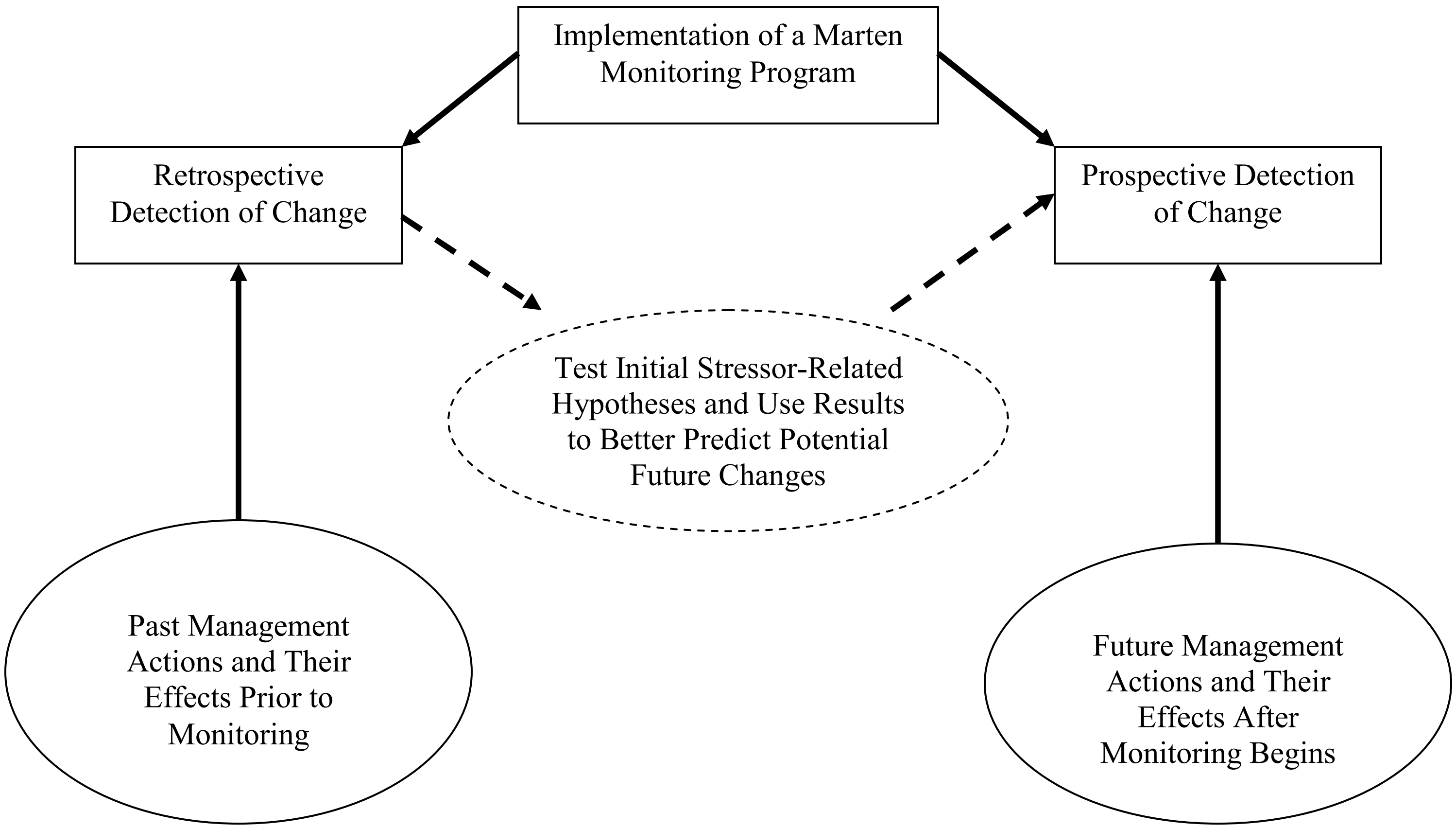


Figure 5. Conceptual model linking the primary stressors for American martens in the Lake Tahoe Basin to their ecological consequences, and how these consequences are related to population responses.

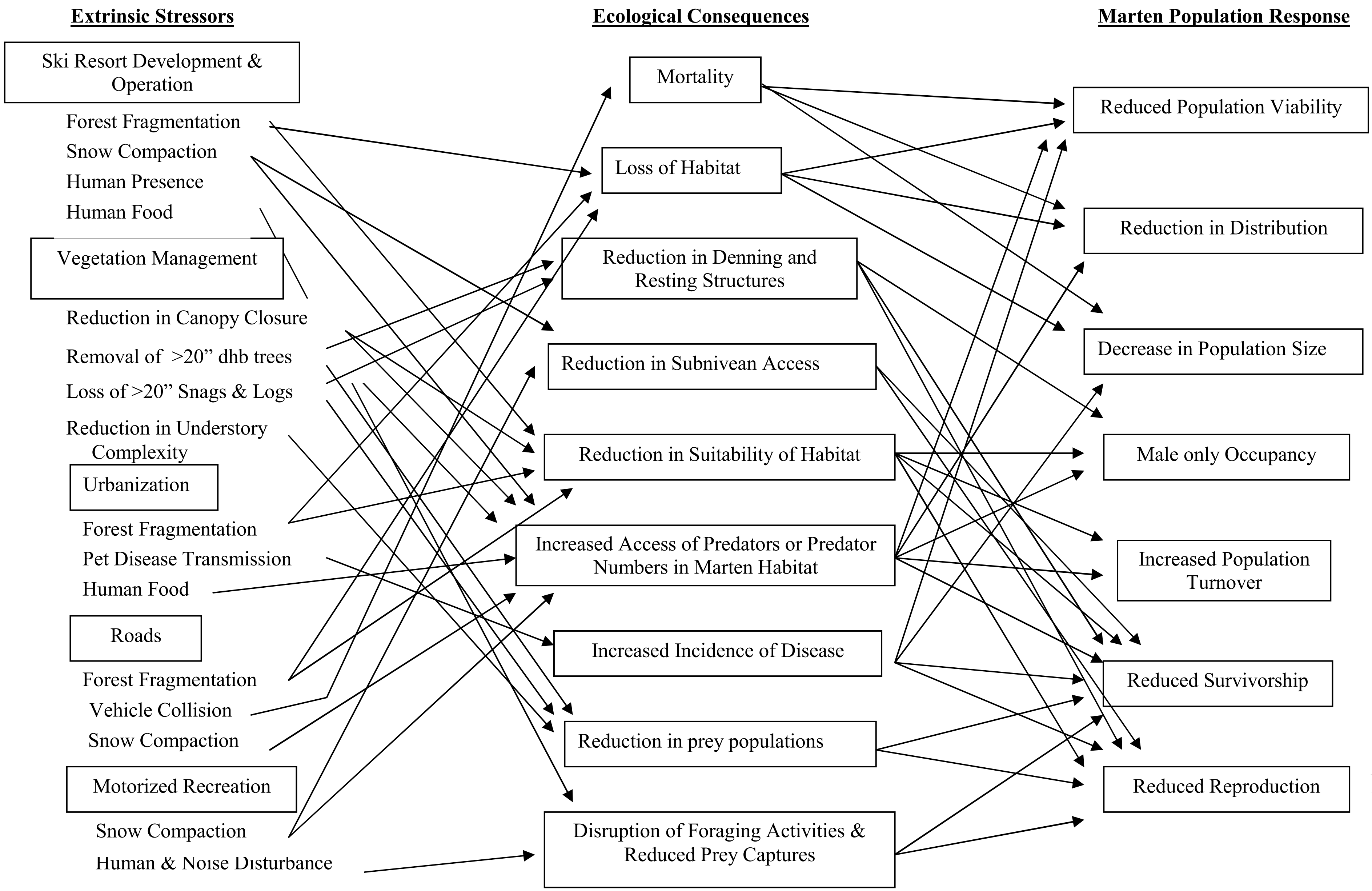


Figure 6.  Distribution and results surveys using detection devices for American martens from 1993-2005 relative to 2.5 and 3.0 km$^2$ hexagonal sample units.

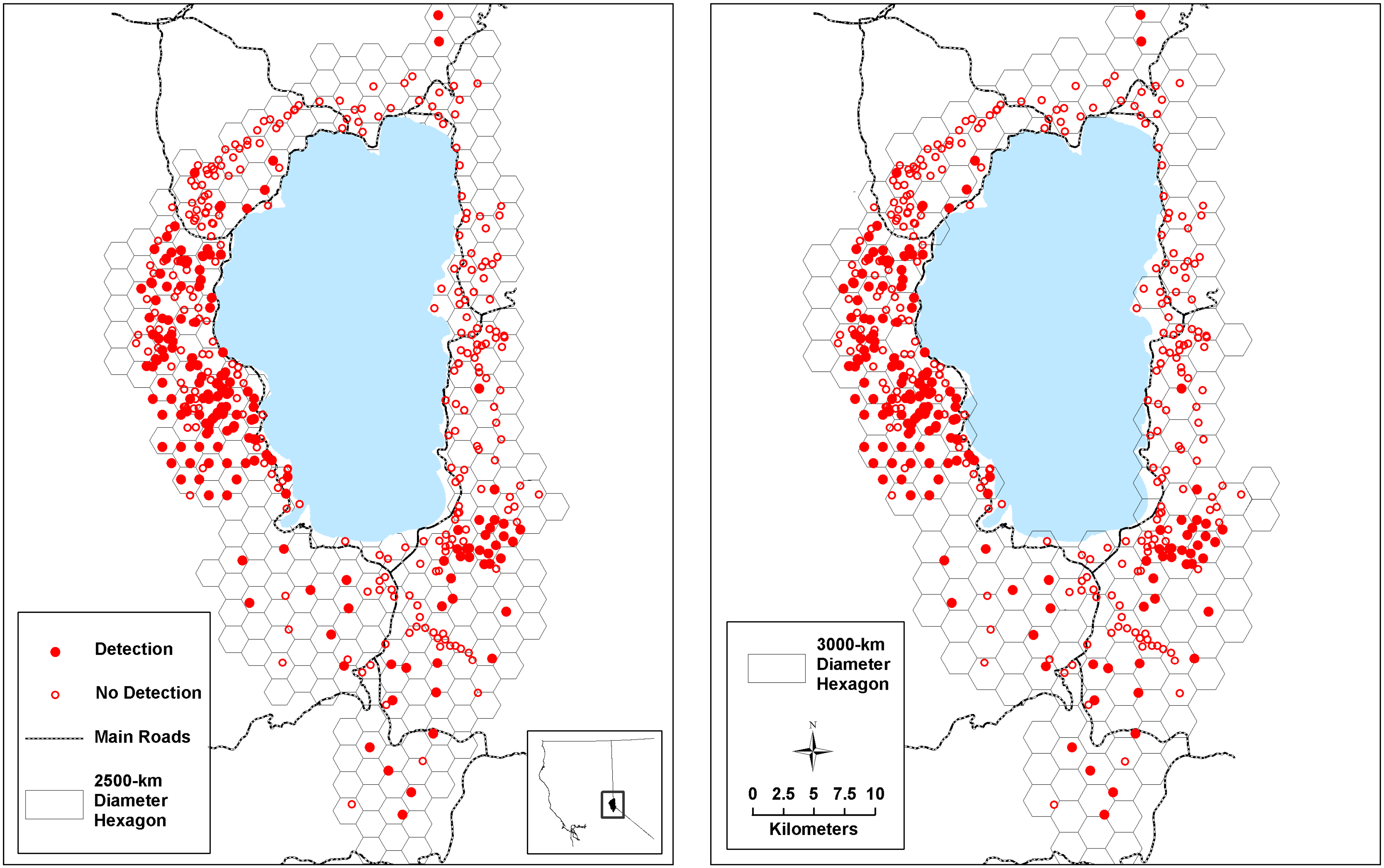


Figure 7. Sample unit and track plate station array.

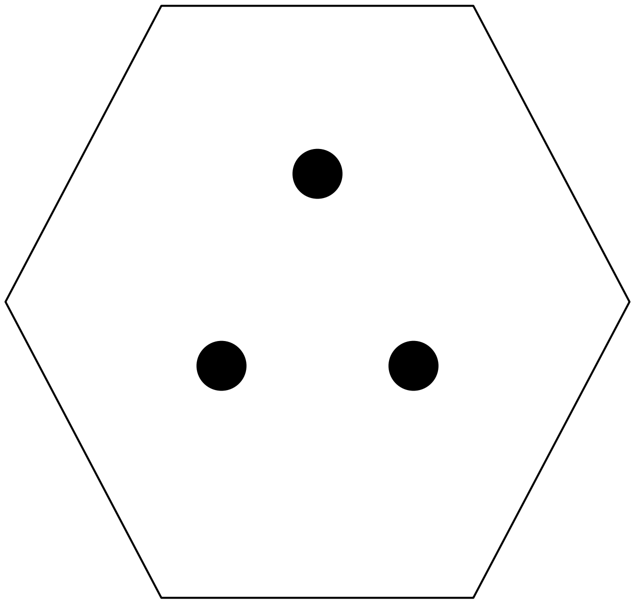


Figure 8. Detection probability estimated for American martens at 3-station track plate sample units on the west shore of Lake Tahoe in the summer of 2003.

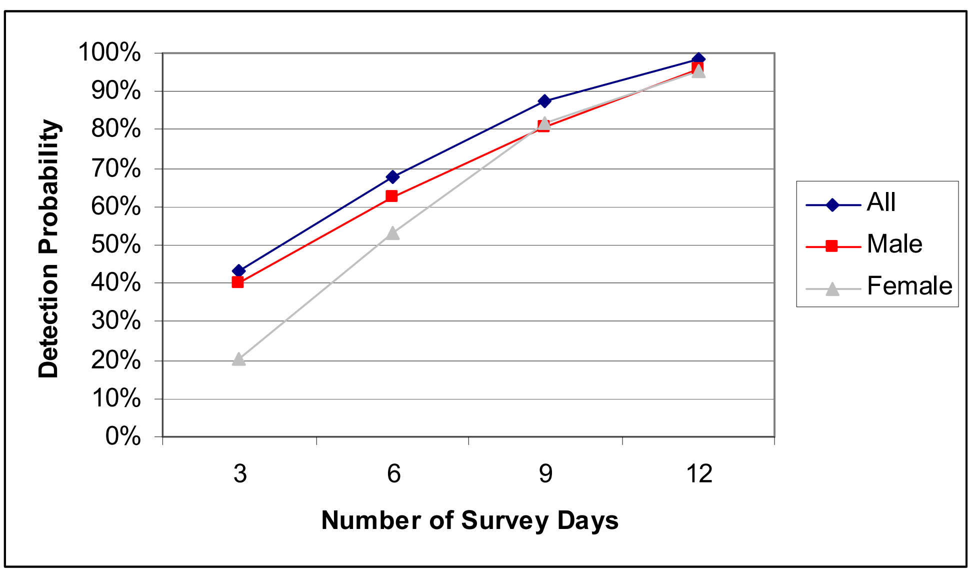


Figure 9. Selected sample units for inclusion into the marten monitoring program. The 110 shaded and 73 un-shaded sample units indicate those included and not included in the monitoring program, respectively.

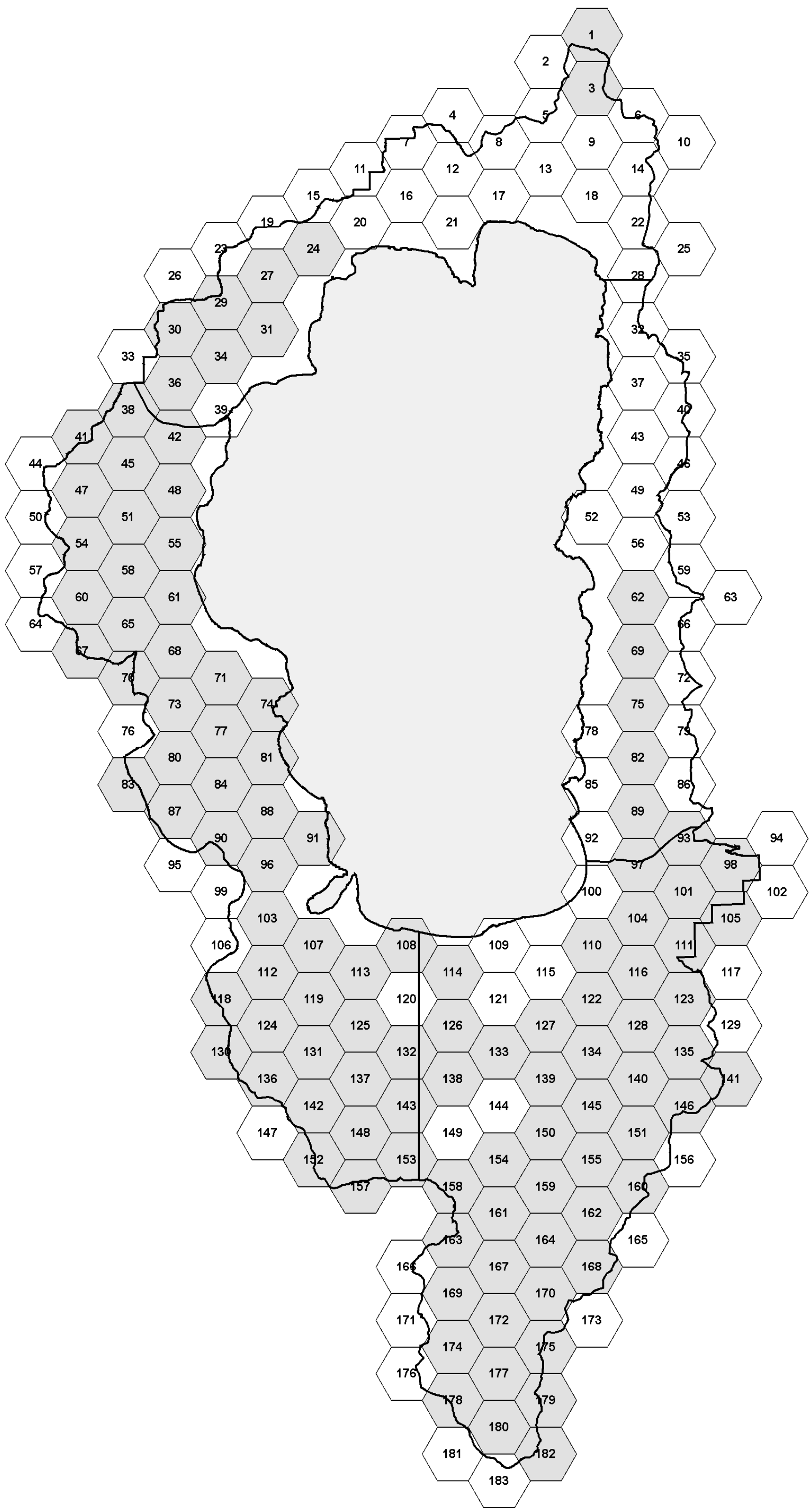
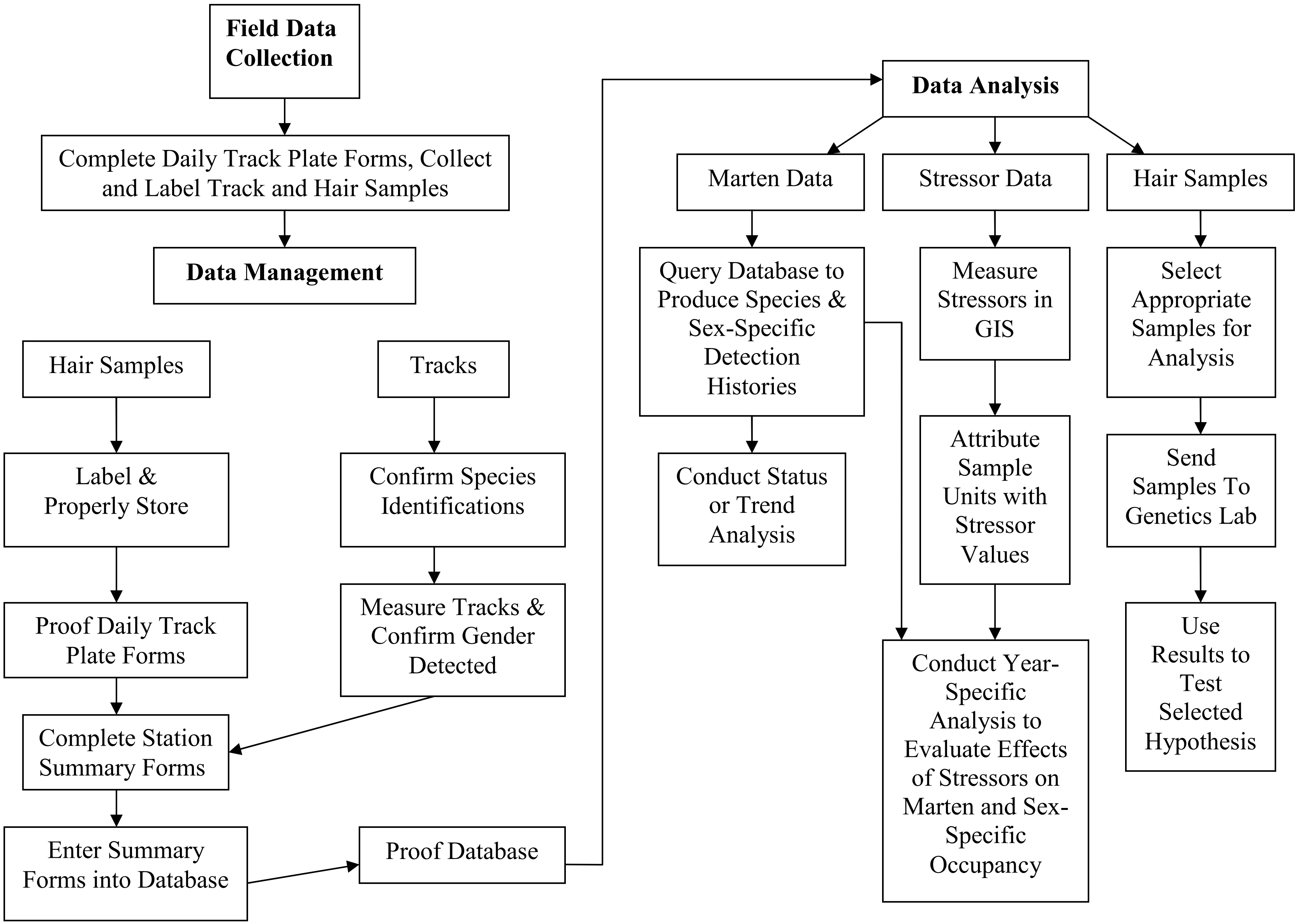


Figure 10.  Flow chart of the sequence of steps involved from field data collection through final analysis.



Appendix 1. This glossary defines frequently used survey design terms that are used throughout the manuscript. Definitions are tailored specifically to noninvasive survey methods, and may not represent the best definitions for other applications. Words in italics are defined elsewhere in the glossary.

DETECTION—Evidence (i.e., track, hair, scat or photo) that confirms the occurrence of a target species at a *station* or *site* during a *sampling occasion*.

DETECTION PROBABILITY (or PROBABILITY OF DETECTION)—A parameter representing the probability of actually detecting a species or individual animal given that it (or its sign) is present at the survey *site*. Detectability can be estimated given an appropriate survey *design*, and is important for accurately estimating both *occupancy* and *abundance* via capture-recapture methods.

DISTRIBUTION—The actual area of species occurrence, typically expressed on a map as either "occupied" or "unoccupied" (or estimated to be in one of these states). Distribution can be displayed as a continuous surface (e.g., as with vector-based map elements) or as a surface divided into subunits (e.g., grid cells)—each indicating *presence* or (inferred) absence. In either case, a given location's state ("1" or "0") can be inferred based on binary detection-nondetection *surveys* at the actual location, or predicted via occurrence models in concert with a rule-based assignment method (e.g., all sites with predicted occupancy of >0.80 are assumed to be occupied).

MONITORING—Performing repeat *surveys* over time, with the goal of quantifying change in *population status* (i.e., *trends*). Monitoring should not be confused with repeat *sampling occasions* (sometimes referred to as "checks" or "visits"), which are conducted within a single *survey* and either allow the estimation of detection probabilities or provide an increase in overall *detectability* at the site.

OCCUPANCY—A population state variable representing the proportion of *sites* estimated to be occupied (or in the case of wide-ranging species such as carnivores, the proportion used) by a species of interest. If an appropriate survey *design* (e.g., randomly chosen *sites*) is employed, occupancy is also considered an estimate of the proportion of the *survey area* occupied (or used) by the species. Occupancy is not estimated for an individual *site*, but only for *surveys* with multiple sites. Thus, it is differentiated from *presence* in that it is an estimated parameter whose value falls between 0 and 1.

OCCURRENCE—Typically a synonym for *occupancy*, occurrence is also synonymous with *presence*—as in the phrase *extent of occurrence*.

SAMPLE UNIT—A statistical unit of analysis. For example, if a *site* comprising five survey *stations* is the *sample unit*, then a detection at any number of the stations results in a single detection recorded for the site. Elsewhere, the term sample unit has sometimes been used synonymously with site, and also in a non-probability sense to refer to the subunits of a *survey* aimed at detecting a target species in an area of interest. We do not use it in this manner.

STATION—A location within a *site* or *survey area* at which a *detection* attempt is made during a *sampling occasion*. Stations are typically assumed to be dependent (i.e., a detection at one station may affect detection at other stations within the site or survey area), and detections at multiple *stations* are often collapsed into *binary data* or *count data* at the level of the site for occupancy or relative abundance assessments. Alternately, stations are the locations at which individual animals are detected for *capture-recapture* approaches used to estimate population size.

SURVEY— One or more attempts (i.e., *sampling occasions*) to detect a species at either a single location or across many *sites* with the intention of making inferences about species *occurrence* or population size. Survey outcomes can include assessments of species *presence*, estimates of *occupancy*, predicted *distributions*, mean count per unit area or per survey time, or estimated population size.

SURVEY AREA—The area within which the *survey* results and resulting inferences are relevant. This is analogous to the statistical population. Survey *sites* should be distributed appropriately within the survey area and based on a statistical probability model if inferences gained from site data are to be unbiased.

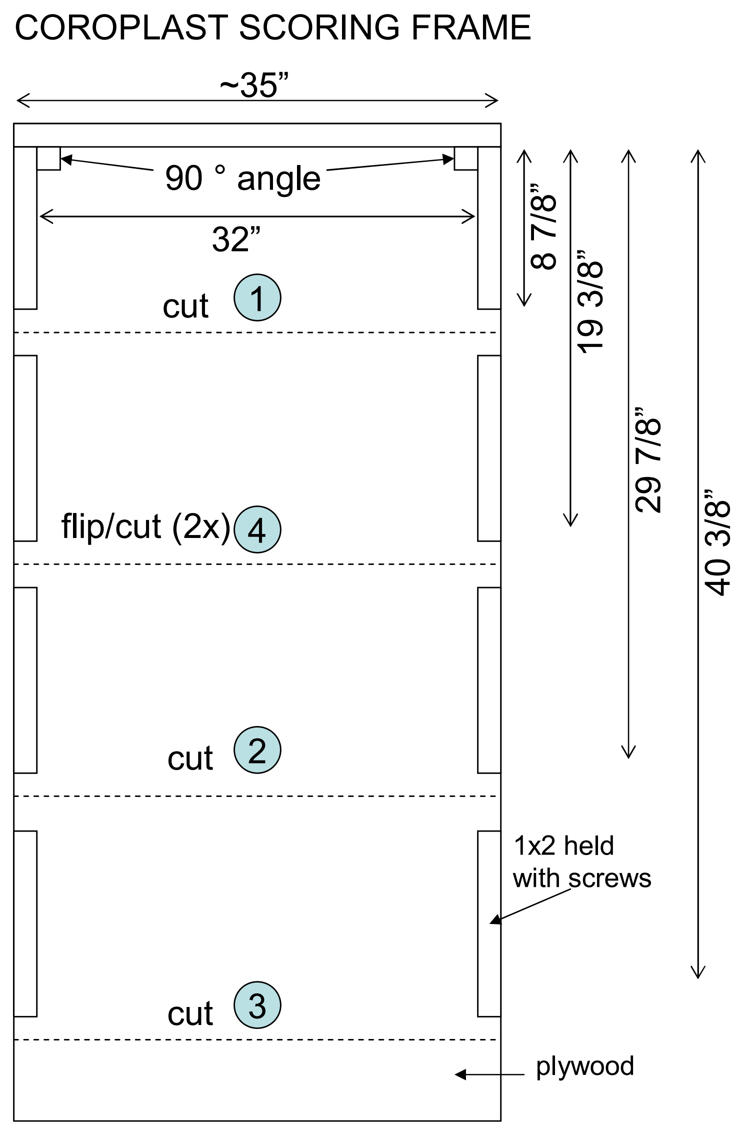
SURVEY DURATION—The amount of time or the number of *sampling occasions* comprising the *survey*. The sampling duration affects *detection probability*, and should be chosen based on both the home range of the target species and the size of the survey *site.*

VISIT—A synonym for *sampling occasion* that is often encountered in the carnivore literature. Visit is becoming a less accurate descriptor with the advent of noninvasive methods that permit *sampling durations* to be subjectively parsed after the fact (e.g., when remote cameras provide continuous sampling), and because a visit by the observer can be confused with a “visit” by the target species.

Appendix 2. Track plate box, track plate, and hair snare design specifications.

Coroplast track plate box material source. We have successfully used: Towers Marketing, 1015 Arrowsmith Street, Eugene, Oregon 97402. (541) 342-8665. Contact: Bob

Explain that you are using the coroplast for mammal track cubby boxes. The dimensions are 32” x 44” with the corrugations running parallel to the 44” side. Use following guidelines to cut the sheets into smaller units.

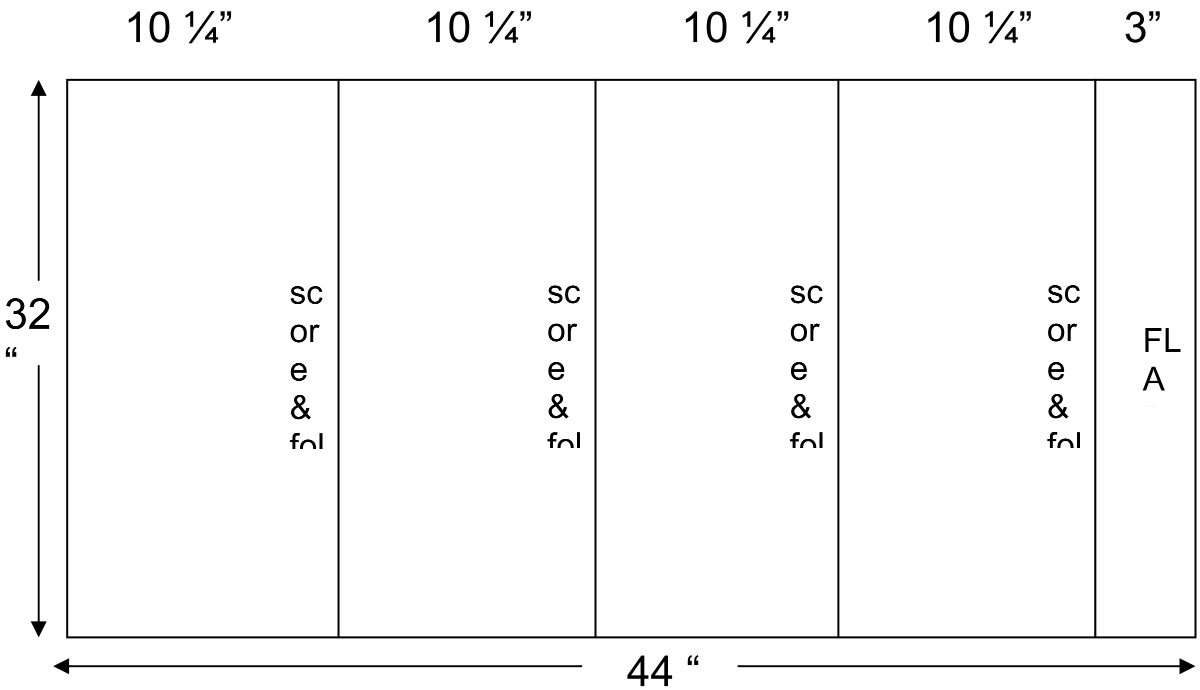


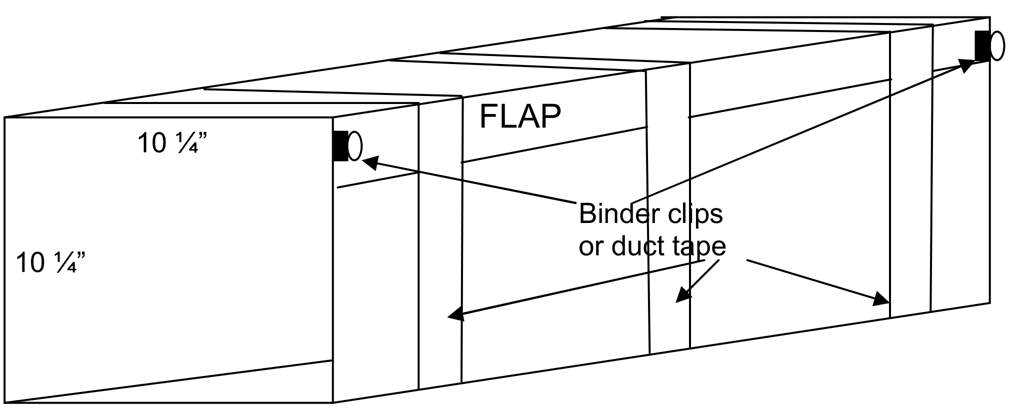

These measurements (right side) assume that a box cutter is used and that the board used to cut against is exactly 1 ½ inch. Set the box cutter at its shortest depth and make cuts 1, 2, and 3; flip the coroplast over and make a double cut at 4 about 1/8” apart. This allows you to accordion the board. If time allows, make double cuts at all corners to aid in bending the seams. **Caution: do not cut deeply enough to cut the outer layer of coroplast.**

Individual coroplast track plate box specifications.

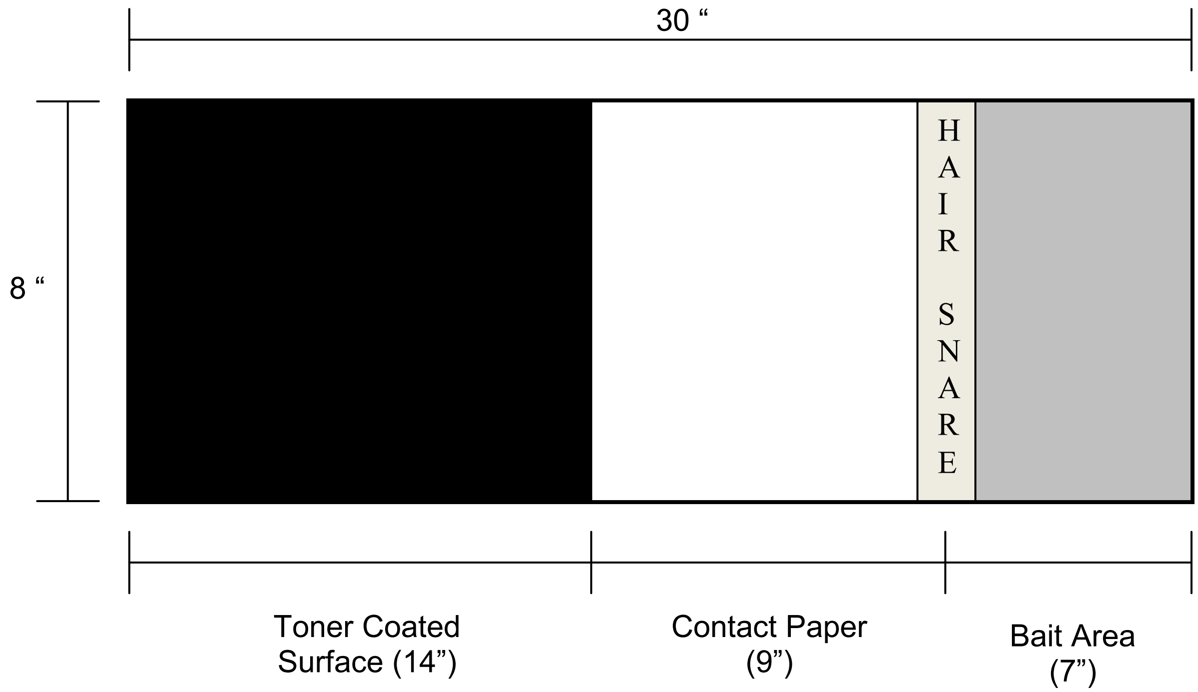
## Coroplast™ Cubby

Coroplast™ is a corrugated plastic material (see coroplast.com/ for info). For our purposes we use black ¼ inch sheets cut to 32” by 44” with the corrugations running parallel to the length to provide better strength. We have been buying through Towers Marketing (800-285-1667) in Eugene, Oregon, which has been stocking this size sheet in the proper orientation. Current cost (January 2004) is $3.50 per sheet + shipping.



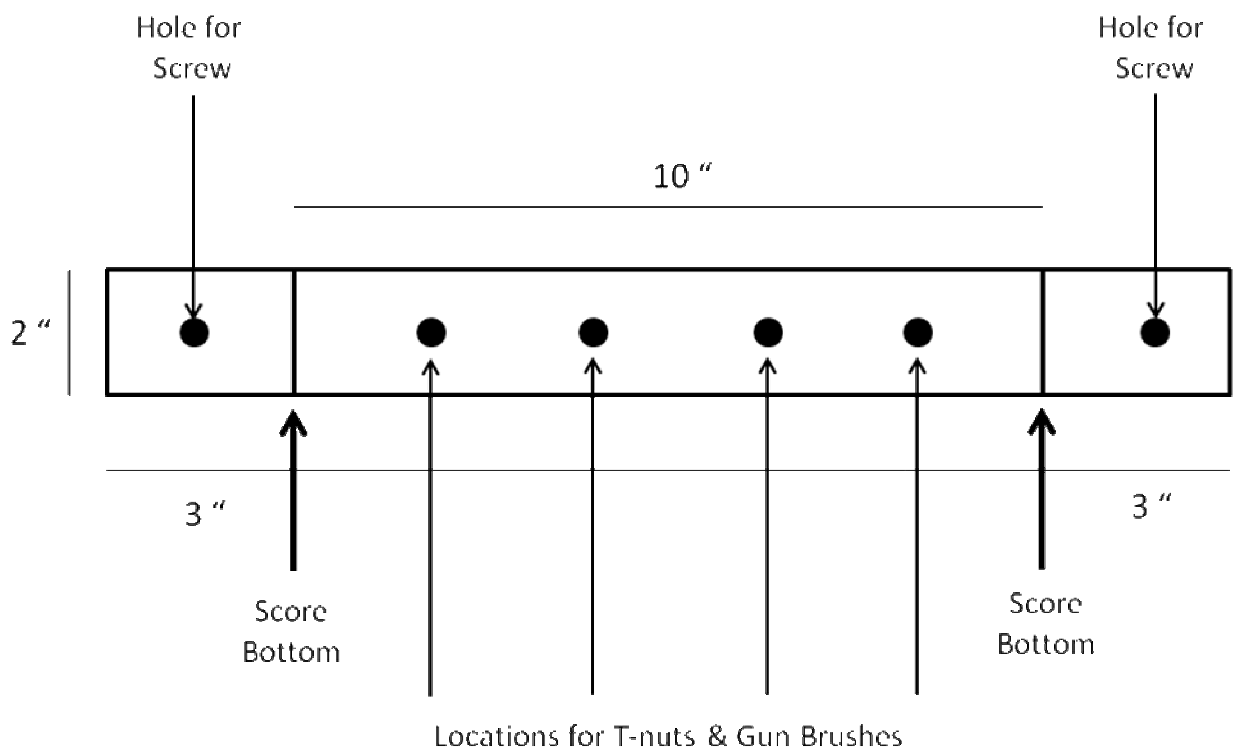



Track Plate Specifications and hair snare placement.

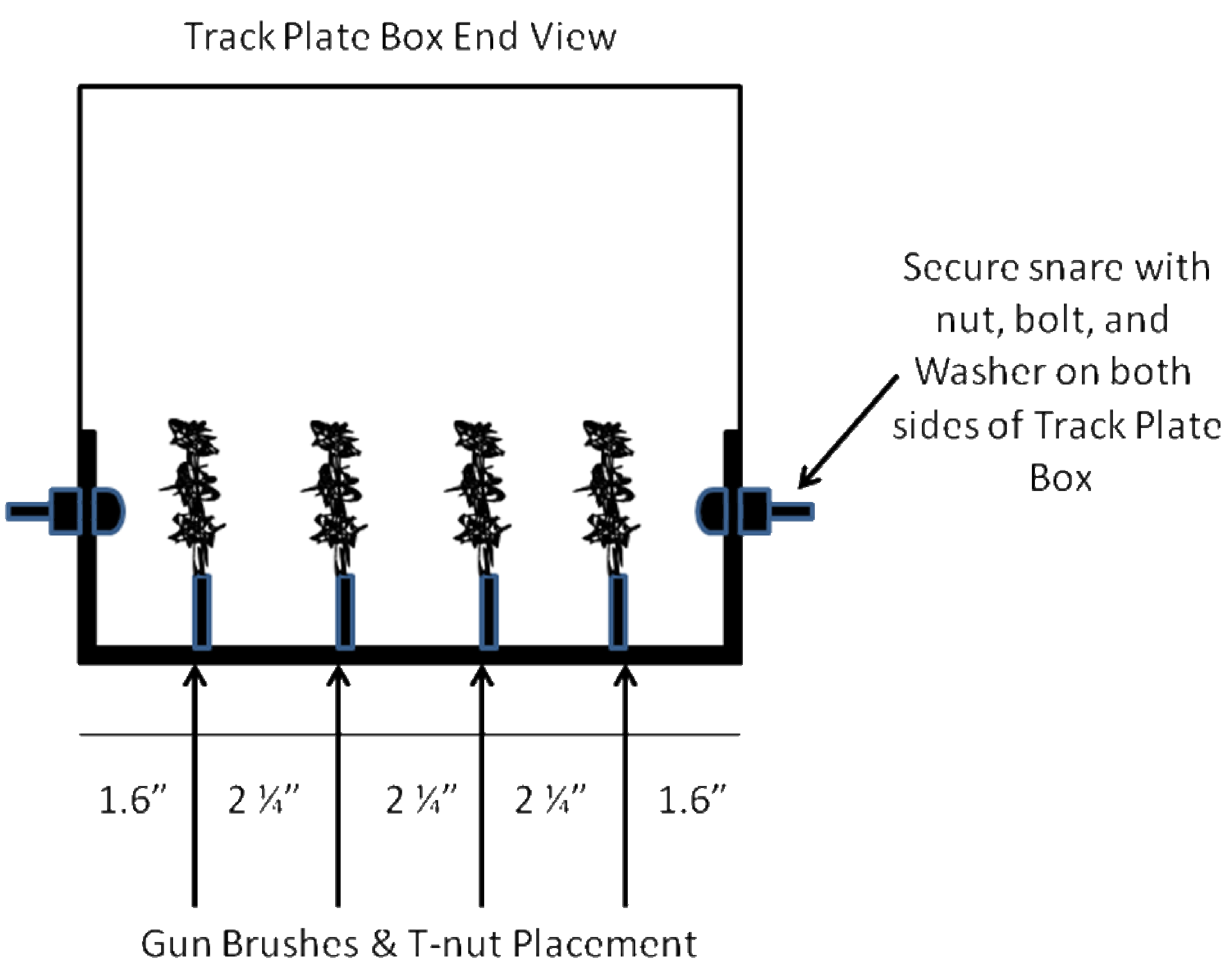


Hair Snare Specifications: Hair snares fit into track plate boxes in the position described above. Equipment list (per track plate box): Coroplast, 30 caliber threaded bronze rifle clearing brushes (4), t-nuts (4) to fit 8-32 threaded gun brushes, duct tape to seal bottom of t-nuts onto Coroplast, screws (2), bolts (2), washers (2).

Hair Snare Design. Use Coroplast to create the snare base, holes must be pre cut to fit t-nuts or screws.



Hair Snare Specifications: Securing Hair Snare to Track Plate Box.



Appendix 3. Marten track measurement and sex discrimination protocol. This section includes relevant excerpts from Slauson et. al. (submitted); refer to the complete manuscript for additional details.

Getting Started

It is best to have read and understand the following papers of track identification and measurement prior to measuring tracks for the purpose of sex discrimination: Taylor and Raphael 1988, Zielinski and Truex 1995, and Slauson et al. (submitted). Next, make sure you are familiar with the nomenclature for track elements described in Figure A3-1.

Measuring Tracks

*Assessing track quality*. Because track quality can affect measurements taken, exclude all tracks that lack clear registration of two of the three main interdigital pads (I3 and I4; Figure A3-2) and toe pads 2-5 (Figure A3-2). To facilitate assessing track quality, use the 3 quality categories from Slauson et al. (submitted): (1) all details of interdigital pads 3-4 and toes 2-5 clearly register (Figure A3-2) (2) all interdigital pads 3-4 and toes 2-5 register, but margins are clearly not complete (Figure A3-2) and (3) size or detail of interdigital and toe pads clearly absent, reduced, or mostly obscured, or the track is distorted due to turning, smudging, or excess moisture (Figure A3-2). Only used tracks with a quality of 1 or 2 for measurement.

*Fore Versus Hind Foot Distinction*. There are consistent differences in the size and dimensions of fore versus hind feet in martens (Taylor and Raphael 1988). It is fairly common for fore feet to appear on track plates for martens. Slauson et al. (submitted) based sex discrimination on measurements from fore feet only for marten, and primarily on fore feet for fisher. Hind and fore feet can typically be distinguished using several characteristics collectively (Figure A3-3). First, heel pads register on track plates only for fore feet, but rarely are recorded on track plates. Second, while hind feet are usually only slightly smaller in total length, the fore feet are typically noticeably wider due to greater spacing between fore foot toes, especially D3-4 (Figure A3-3). Third, the sizes of the interdigital pads are larger in fore feet, especially I4 than hind feet. Other features include a greater distance between I3 and the middle toes and a more rounded appearance to the interdigital pads of the hind feet (Figure A3-3). Use these features collectively to identify fore feet for measurement.

*Track mensuration and measurement*. All track measurements should be made to the 0.01 mm using electronic digital calipers (e.g., Browne and Sharpe, Kingston, USA). To apply the general technique developed by Zielinski and Truex (1995) it is necessary to determine whether the track was made by the right or left foot. Use these 3 rules, adapted from Zielinski and Truex (1995), to guide right and left foot determination: (1) the medial most digit (the 'thumb'; 1 in Figure A3-1) was generally smaller (if present, often absent altogether) and posterior to the remaining toe pads and was often even with the largest interdigital pad (2) a small metacarpal pad (I1) was posterior and lateral to the thumb, quite close to the main interdigital pads (I2, I3, I4). The thumb and the metacarpal pad (I1) are on the medial side of the track; thus if they were on the left side of the track as in Figure A3-1, the track was from the right foot. (3) If both of these are lacking, the combination of the 5th digit being the most posterior and the largest metacarpal pad (I4) occurring on the same side indicates this is the lateral side of the track; thus if these occur on the right side of the track the track was made by the right foot.

Next, the identified toes and pads are used to create a single reference point by drawing two lines: one connecting the medial margins of 2 and I3, and one connecting the lateral margins of 5 and I3 and bisecting this angle (Zielinski and Truex 1995; Figure 2). This coordinate system allowed for maintenance of precision in Cartesian measurements and a reference point from which other measurements were derived. We collected data from both original and photocopied tracks impressions and 1 observer recorded all measurements for each species. Measurements from photocopies do not alter track dimensions (Zielinski and Truex 1995, Zielinski unpublished data) and in some cases provided easier media for sharing, archiving, and measuring tracks. Tracks were measured following the methods described by Zielinski and Truex (1995), and all tracks were measured to the 0.01 mm using electronic digital calipers (Browne and Sharpe, Kingston, USA).

*Track variables*. For marten tracks, measure total length, the overall track length measured from the anterior most toe pad margin (usually toe 3 or 4 in Figure 1) to the posterior interdigital pad margin (I2 or I4).

Discriminant function for determining sex of M. a. sierrae tracks. *M. a. sierrae* tracks: sex = (Total Length: base I4 to tip of either leading toes D2-3 left foot, D3-4 right) – 30.75; where >0 is a male and <0 is a female. This single variable discriminant function for *M. a. sierrae* correctly classified 100% of individual tracks measured by Slauson et al. (submitted).

Use the following decision tree to guide mensuration of tracks and for the conclusion of presence of male, female, or both sexes on each sheet of Con-tact© paper. Decision tree for application of Martes sex discrimination methods to tracks collected on track plates. dfxn = discriminant function.

---

1. Marten tracks present (Taylor and Raphael 1988)……………………………….....2
1. Marten tracks absent……………………………………………………………STOP

  2. Tracks of quality 1-2 (I4 and D2-4 clearly register)……..……………………….3
  2. Tracks quality 3……………………………………STOP, Sex ID not possible.

    3. 1 quality category 1 or 2 track present……………………………….……………4
    3. >1 quality category 1 or 2 track present……………………………………5

      4. apply M. a. sierrae dfxn, if >0…………………………Male marten present
      4. apply M. a. sierrae dfxn, if <0……………………..…Female marten present

        5. Measure all quality tracks, apply
           dxn (step 7, 8, or 9), if all either <0
           or all >0………………………………….…….………One sex is present
        5. Measure all quality tracks, apply
           dfxn (step 7, 8, or 9),
           if not all either <0 or all >0……………...………...........................6

          6. Two distinct size clusters of tracks present, one
             >0 and one <0, each cluster represents a logical
             sequence of tracks (e.g., right and left print
             sequences match measurement clustering) on
             the Con-tact© sheet…………………Both sexes present
          6.. Tracks with measurements <0 and >0 do not
                logically cluster, variation appears to be within
                a single track sequence or indistinguishable,
                take mean measurements and apply dfxn
                (step 7, 8, or 9)……………………………One sex present

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*Use Taylor and Raphael 1988 and Zielinski and Truex 1995 to assist identification.

Figure A3-1. Schematic diagram, with 3 example measurements, for a right-footed *Martes* track collected from sooted track impressions on white Contact© paper. Toe pads are identified with numbers (1-5) while interdigital pads and the heel pad are represented with letters (I1-I4, H). The ordinate of the Cartesian grid is formed by bisecting the angle of intersection created by lines joining the medial margins of 2 and I3, and the lateral margins of 5 and I3 (adapted from Zielinski and Truex 1995). TR1 = Total Length, TR4 = I3-4 Width, Y122 = I3 Height.

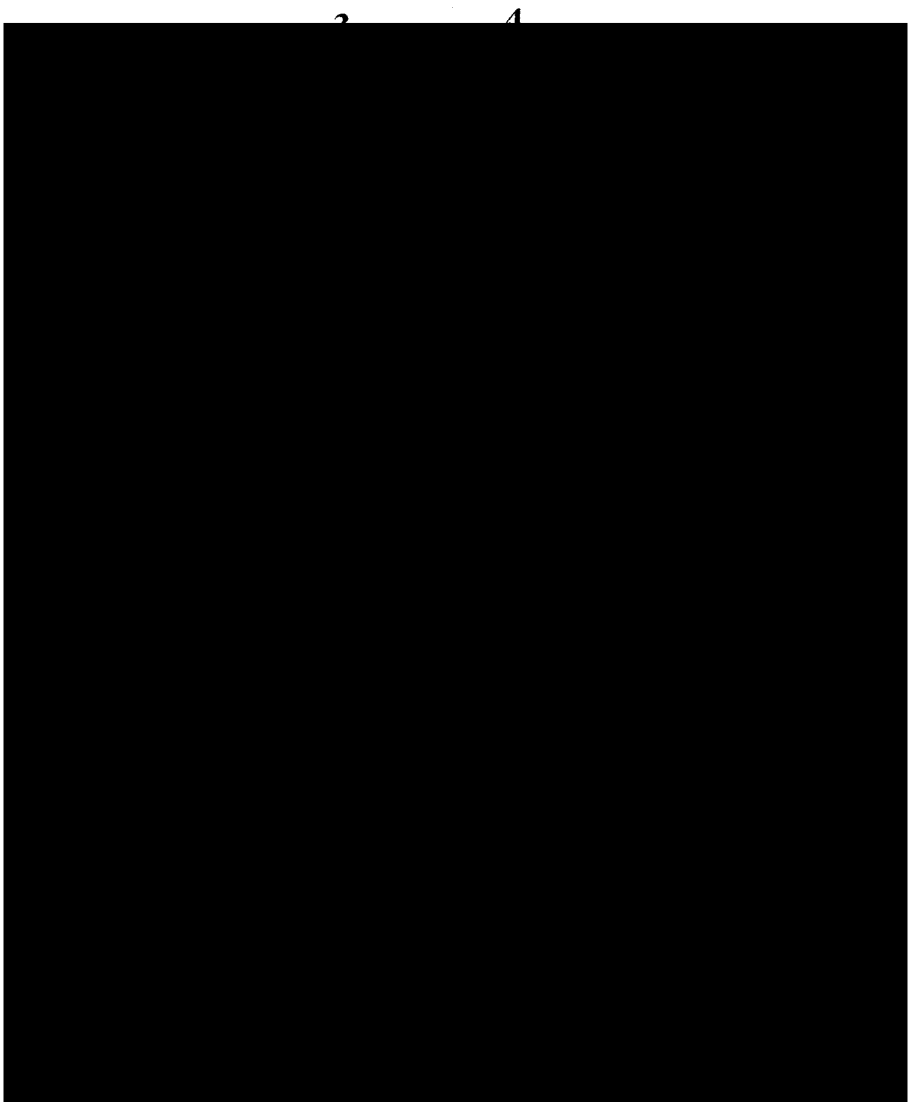

Figure A3-2. Three tracks of the American marten showing typical examples of the quality of individual track impressions. Each track illustrates characteristics of our 3-category quality ranking, with the most detailed on the left (category 1), moderate detail in the center (category 2), and low quality (category 3), unsuitable for measurement, on the right.

**Category 1** **Category 2** **Category 3**

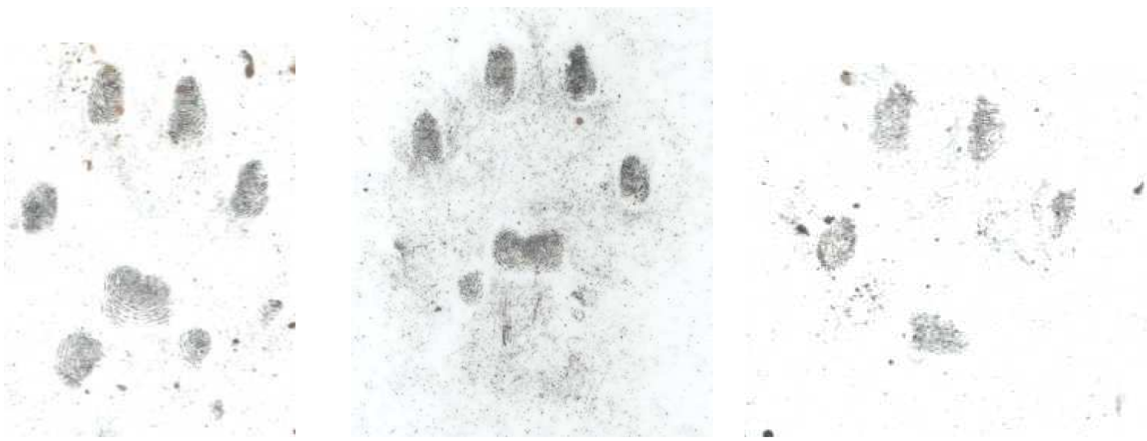

Figure A3-3. Fore feet (outermost left and right tracks) and hind feet (innermost left and right tracks) of American marten (left pair) and fisher (right pair) tracks from track plates.

Appendix 4. Required field equipment.

EQUIPMENT CHECKLIST

**Navigation to Stations**

Compass, Topographic map, DOQQ (if necessary), UTMs for stations, GPS unit, altimeter, flagging, sharpie.

**Establishing and Checking Track Plate Stations**

**Track Plate Boxes** (see specifications in Appendix 2).

**Track Plates**: Aluminum (20 x 76.2 x 0.1 cm).

**Toner** *Non-toxic* copier toner. Best to buy the bulk refilling containers of toner, not to buy cartridges and empty them. Carry toner into the field in a large Nalgene or similarly durable bottle. You can also use splash guards on the mouths of bottle to reduce over pouring of toner.

**Make-up Brush**. These are used to spread the toner evenly on the track plates.

**Contact Paper** (cut for plates and for pulling soot prints): Use WHITE contact paper not clear. Other colors are not as useful for viewing details and making measurements. Try and order large rolls . The rolls come 18" wide, with inch marks along the sheet margins. Thus you can just measure and cut at 10 inch intervals, then cut each 10" sheet in half to produce a 10" x 9" sheet.

**Document Protectors** These are used for putting labeled contact paper sheets with tracks in that are collected in the field **.** These are typically available at office supply stores.

**Bait and Bait Cooler** It is best to buy frozen chicken drumsticks and have a designated bait freezer. Frozen baits can be stored in smaller bags of 3 so they can easy removed when visiting stations and this can reduce the mess from melting. Take bait into the field in bait coolers used only for bait and wash them out frequently. Treat all bait and surfaces bait comes into contact as potentially having salmonella. Try not to come into direct contact with bait and wash with anti-bacterial soap as soon as possible after. You can turn bait bags inside out and use like a glove to disperse new bait or to collect old bait.

**Digital cameras:** These are used for photographing tracks on toner only.

**Standard items:** Duct Tape, Zip Ties, Data forms, large binder clips, sealable plastic bags (quart and gallon) for general use (e.g., hair sample and bait storage).

**Hair Sample Collecting**

Tubes with Desiccant

Sharpies, field pack, pocket knife, tatum (field clipboard capable of holding field forms, document protectors, and extra contract paper).

## **Safety**

Radio (check batteries!), First Aid Kit, Antibacterial soap, Water, electrolytes, food.

Appendix 5. Descriptions of associated files and instructions on how to download them.

To accessing files at the WO public ftp site through a web browser, type the following address into the web browser: ftp://ftp2.fs.fed.us/incoming/psw

Navigate through the following folder pathway to reach the files described below:

rsl>Slauson>Marten_Monitoring_Lake_Tahoe_Basin

Master_Station_UTMs.xls This file contains the UTMs for all the station for all sample units located in the Lake Tahoe Basin. The Master_Sample_Unit is the unique number associated with each sample unit. The station indicates the unique number for each station 1-3 for each sample unit. The UTMN and UTME provide the x and y coordinates and the Selected column indicates whether the sample unit was selected for inclusion into the monitoring program.

tri.prj, tri.shp, tri.shx, tri.dbf These are the GIS shape files for the station locations.

master_hex_coverage.shp.xml, master_hex_coverage.prj, master_hex_coverage.shp, master_hex_coverage.shx, and master_hex_coverage.dbf These are the GIS shape files for the sample unit boundaries.

Marten_Monitoring_Data_Forms.xls This file contains examples of the data forms to be used.

Marten_Occupancy_Estimation.sas This file contains the SAS code to run the occupancy estimation analysis for the marten data.